UNIVERSITY OF MICHIGAN
APR 12
PERIODICAL READING ROOM

1831 1955

SED · OMNIA · DISPOSVISTI

YORK · OXFORD · CAMBRIDGE · EDINBURGH · DUBLIN · BRISTOL · LIVERPOOL · NEWCASTLE · BIRMINGHAM · GLASGOW · PLYMOUTH · MANCHESTER · CORK · SOUTHAMPTON · SWANSEA · IPSWICH · BELFAST · HULL · CHELTENHAM · LEEDS

BATH · NOTTINGHAM · DUNDEE · NORWICH · EXETER · BRIGHTON · BRADFORD · SHEFFIELD · SOUTHPORT · MONTREAL · CARDIFF · TORONTO · DOVER · S. AFRICA · WINNIPEG · LEICESTER · PORTSMOUTH · AUSTRALIA · BOURNEMOUTH · LONDON

ABERDEEN · BLACKPOOL

The ADVANCEMENT OF SCIENCE

Vol. XI, No. 44

The Ancient University
Genetics and the Advancement of Science
Semi-Conductors
Science and Industry
Heating and Ventilation
Science and the Herring Fishery
Leonardo da Vinci
Coal and Britain's Future
Integration of German Refugees

Published by the
BRITISH ASSOCIATION
for the Advancement of Science
Burlington House, London, W.1.
March 1955 Tel.: Regent 2109

Price: Seven Shillings and Sixpence

The Equatorie of the Planetis

Edited by D. J. PRICE

Reproduced with a translation and critical apparatus from a fourteenth century manuscript at Peterhouse, Cambridge. The editor considers the arguments for the ascription of this scientific text to Chaucer.

52*s.* 6*d. net*

Petrology for Students

A. HARKER

"Harker" was first published in 1895. This eighth edition has been thoroughly revised by C. E. TILLEY, S. R. NOCKOLDS and M. BLACK.

18*s. net*

Actions of Radiations on Living Cells

D. E. LEA

"The most important and authoritative work now available" —NATURE.

Second edition revised by L. H. GRAY. 30*s. net*

CAMBRIDGE UNIVERSITY PRESS

ADLARD & SON LTD.

BARTHOLOMEW PRESS, DORKING, SURREY

Telephone : Dorking 3874

PRINTERS TO SCIENTIFIC SOCIETIES

Experienced in mathematical formulae composition

CIMBRA

(Comércio Império Britânico-Brasil)

IMPORTERS OF

ROCK CRYSTAL QUARTZ

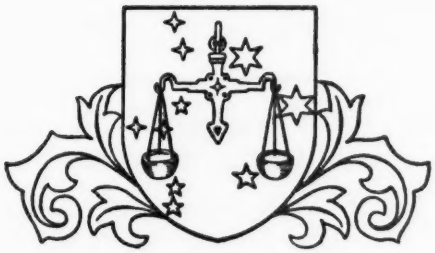
FOR PIEZO ELECTRIC AND OPTICAL PURPOSES

We are at your service PLEASE CONSULT US

CIMBRA LIMITED

123 PALL MALL, LONDON, S.W.1 WHITEHALL 9681 CIMBRALON, PICCY, LONDON

A

1831  1955

THE ADVANCEMENT OF SCIENCE

VOL. XI, No. 44 MARCH, 1955

CONTENTS

	PAGE
Officers and Council	374
The Ancient University, *by* J. T. Christie	375
Genetics and the Advancement of Science, *by* Prof. S. C. Harland, F.R.S., and Prof. L. S. Penrose, F.R.S.	383
Semi-Conductors, Transistors and Photo-Cells, *by* Dr. R. A. Smith	391
The Work of the Science and Industry Committee, *by* Prof. C. F. Carter	404
Heating and Ventilation: Report of a Symposium	409
Science and the Herring Fishery, *by* R. S. Glover	426
Leonardo da Vinci, *by* Dr. F. Sherwood Taylor	435
Coal and Britain's Future: Report of a Symposium	441
The Integration of the German Refugees, 1945–1953, *by* R. E. H. Mellor	465
Index to Advancement of Science, Volume XI	475

OFFICERS AND COUNCIL OF THE BRITISH ASSOCIATION, 1955-6

PATRON.

HER MAJESTY THE QUEEN.

PRESIDENT, 1955.

Prof. Sir ROBERT ROBINSON, O.M., F.R.S.

GENERAL TREASURER.

M. G. BENNETT.

GENERAL SECRETARIES.

Sir RICHARD SOUTHWELL, F.R.S. | Dr. GEORGE TAYLOR.

ORDINARY MEMBERS OF THE COUNCIL.

R. J. BARTLETT.
Prof. L. F. BATES, F.R.S.
M. C. BURKITT.
P. RITCHIE CALDER, C.B.E.
Prof. H. G. CHAMPION, C.I.E.
Prof. G. R. CLEMO, F.R.S.
Prof. H. P. GILDING.
Dr. D. B. HARDEN.
A. C. HARTLEY, C.B.E.
Prof. H. R. HEWER.
Prof. K. S. ISLES.
Dr. WILLIS JACKSON, F.R.S.
A. GRAY JONES.
Sir HAROLD SPENCER JONES, F.R.S.
Dr. H. D. KAY, C.B.E., F.R.S.
Sir BEN LOCKSPEISER, K.C.B., F.R.S.
Prof. KATHLEEN LONSDALE, F.R.S.
Prof. A. D. MACDONALD.
J. WICKHAM MURRAY, O.B.E.
Prof. F. W. PAISH.
Dr. C. F. A. PANTIN, F.R.S.
Prof. W. J. PUGH, O.B.E., F.R.S.
Dr. J. RAMSBOTTOM, O.B.E.
Prof. L. DUDLEY STAMP, C.B.E.
Dr. W. E. SWINTON.
Prof. P. E. VERNON.
Prof. W. WARDLAW, C.B.E.
W. H. WILCOCKSON.
Prof. S. W. WOOLDRIDGE, C.B.E.
Dr. N. C. WRIGHT.

EX-OFFICIO MEMBERS OF THE COUNCIL.

Past-Presidents of the Association, the President for the year, the President and Vice-Presidents for the ensuing Annual Meeting, past and present General Treasurers and General Secretaries, and the Local Treasurers and Local Secretaries for the Annual Meetings immediately past and ensuing.

PAST PRESIDENTS OF THE ASSOCIATION.

H.R.H. THE DUKE OF WINDSOR, K.G., F.R.S. (1926).
Sir HENRY DALE, O.M., G.B.E., F.R.S. (1947).
Sir HENRY TIZARD, G.C.B., F.R.S. (1948).
Sir JOHN RUSSELL, O.B.E., F.R.S. (1949).
Sir HAROLD HARTLEY, K.C.V.O., C.B.E., M.C., F.R.S. (1950).
H.R.H. The DUKE of EDINBURGH, K.G., K.T., F.R.S. (1951).
Prof. A. V. HILL, C.H., O.B.E., F.R.S. (1952).
Sir EDWARD APPLETON, G.B.E., K.C.B., F.R.S. (1953).
The Lord ADRIAN, O.M., P.R.S. (1954).

PAST GENERAL OFFICERS OF THE ASSOCIATION.

Prof. P. G. H. BOSWELL, O.B.E., F.R.S.
Prof. Sir DAVID BRUNT, Sec. R.S.
Sir HAROLD HARTLEY, K.C.V.O., C.B.E., M.C., F.R.S.
Dr. EDWARD HINDLE, F.R.S.
Sir FRANK SMITH, G.C.B., G.B.E., F.R.S.
Prof. F. J. M. STRATTON, O.B.E., F.R.S.
Sir ARTHUR TRUEMAN, K.B.E., F.R.S.

HON. AUDITORS.

Sir JOHN SIMONSEN, F.R.S. | Dr. H. J. T. ELLINGHAM.

SECRETARY.

Sir GEORGE V. ALLEN, C.B.E.

THE ANCIENT UNIVERSITY[1]

by

J. T. CHRISTIE

WHEN King George III visited the city of Norwich, he remarked to the mayor : ' An ancient City, Mr. Mayor.' ' Indeed, your Majesty,' was the reply, ' but not so ancient as it was.' Nothing can prevent Oxford University from being ancient, chronologically. It still bears, and will always bear, the marks of all institutions that are both ancient and English : the haphazard nature of its growth, its anomalous and illogical organisation, its distrust of too strong a central authority, and its apparent repudiation of the Planning spirit. What planner, in his senses, would try to organise in a single town twenty-two separate Colleges, not to mention a number of more modern appendages, of different size, of different wealth, different traditions and different social status—and then call it a University ? I once tried to explain this to a German friend who had descended on me for the afternoon from Heidelberg ; he naturally assumed that to each College was allotted a distinct faculty, that, say, Corpus was full of Classics and Magdalen of Mathematicians. I said that this was not so, that at any one College you could find young men studying any one of a dozen different faculties, and he replied ' Is not this very wasteful ? ' It is. But the loss in economy and in organised tidiness is more than balanced, I have come to believe, by educational gain.

I have seen many Universities in the last five years, in this country, in America, and in India, where I spent seven months on an Educational Commission. I soon realised that Oxford and Cambridge, which still represent for a fairly dominant minority the picture of a normal University, are, in fact, unique exceptions, though it is interesting to observe that in our own newer Universities, a system of Halls of Residence is becoming increasingly common. By the educational gain of such a College-system, I mean precisely the cross-division of faculties which it facilitates. In the same College, nay, on the same staircase, you may find, perhaps, on the ground floor a Rugger-playing Chemist, aiming at a good Third, and opposite him a Theology student, prone to introspection ; just above them a shy conventional boy from an ancient boarding school, doing Classics, and across the landing a bright young man from the industrial north, reading English, but chiefly interested in editing a University magazine ; above them all, maybe, the College Chaplain. Inherent in that mixture is education, unconscious education, which is the best kind. This was always so, but nowadays it is more important than ever, because nowadays the threat of a narrow specialisation is stronger than it was, and secondly, because the boy from the poorer home with not enough money for books or amenities, needs just this kind of education, almost more than he needs proficiency in his chosen subject, unless he is an especially brilliant person.

Since my own return to Oxford after some twenty years away, I have been struck by the importance of the small informal meetings of College societies—gatherings of two dozen young men in a room intended for the use of one or two, most of them sitting on the floor for lack of chairs, eating chocolate biscuits and discussing, sooner or later (whatever the title of the paper) such subjects as God, Free-Will and Immortality ! This may well happen—it certainly should—at any University, but the tradition flourishes more easily in the small residential unit like an Oxford or Cambridge College. It is a tradition which breeds tolerance, interest in other points of view, and the ability to disagree generously—qualities which are sorely needed in a modern democracy, and

[1] Address delivered to Section L (Education) on September 2, 1954, during the annual meeting of the Association at Oxford.

the ancient Universities are well qualified to provide them. Moreover, the small cross-section division of a University which we know here as a College can confer a corresponding benefit upon the Senior Common Room—on the teachers as well as the taught. An eminent French economist of my acquaintance, who was critical in some directions of the easy-going Oxford spirit, told me that what the Universities of his country most envied was the daily and nightly commerce of the dons' Common Room. Such commerce is only possible when the unit is small. The College-system is a part of ancient Oxford, but it still has its effect on seniors as well as juniors and also on the relations between them.

I am thinking, as you may guess, of the tutorial system. There is, I know, more than one view about this tradition. To some, the contact of pupil with tutor, of immaturity with ripe wisdom in the quiet surroundings of a College room, seems to give all that is best in education. To others (and I have heard the view expressed with fervency in Scotland) the tutorial system means spoon-feeding for the pupil and a waste of valuable time for the tutor : ' The young man is old enough to stand on his own feet.' Nevertheless, it is my impression that lecturers at many modern Universities, particularly in Arts subjects with classes of over one hundred, look with envy on a system which can find room for the private hour, when a boy can put his private difficulties and a spark can be kindled in the individual mind. I believe that anyone who had himself been an Arts student at Oxford would include the tutorial system among the traditions which are still of value.

In itself, the College system was an integral part of the history of the University as it developed four or five hundred years ago. Some Colleges began by being no more than Halls of Residence for those who came to attend the University ; and some of them had a territorial link, Exeter with the south-west, Jesus with Wales, and so on. Something of the same kind was happening in other European Universities : there was the English College at Rome and at Padua. Why was it that the Colleges here, and here only, achieved a status and a wealth which outshone the University ? There are, no doubt, several reasons, but one, surely, is to be traced to the English temperament. The Englishman who became eminent in after-life and felt inclined to acknowledge by benefactions his debt to the University where he had been bred, bestowed his bounty not on the larger, more abstract body, the University, but upon the smaller, more intimate community of the College, where he had made his friends, where he had worshipped in the Chapel and sat at meat in the Hall. It was the common life that held for him the deepest memories, and gaining a degree was solemn admission to a full brotherhood. At any rate, whatever the reason, the Colleges became richer and stronger at the expense of the University, and it may be argued that at the end of the last century, their influence was too strong. It was possible for a young man to have his whole education within the walls of his College and to miss the chance of wider contacts which a University is intended to provide. And this was equally true of the dons. If we go back further to the middle of the last century, they were all clerics and all bachelors, a formidable thought for the pupil, and, might one add, the psychologist ! A University of that kind was precisely not qualified to meet the needs of a modern world. Oxford has tried to move with the times, to shed what was narrow and cramping but to keep alive traditions, some of them very ancient, which still have their contribution to make.

And certainly the times have been moving. Oxford has changed ; she is, as I said at the outset, less ancient than she was. She has changed, in spite of her traditional background, in more directions than I could hope to discuss in a short time. But I will take two, both of them obvious and unmistakable, one academic and the other social. Academically, there has been in the last forty years a wide and swift expansion of Natural Science. Let those who remember Oxford long ago take a walk round the Parks. Laboratories and Institutes have sprung up on every side, some of them for the study of Sciences whose names were hardly known when I was a boy. It would be absurd to label this great expansion as either good or bad. It was inevitable, and Oxford would not have been true to the cause of learning and the needs of her

children if she had not made such provision. But it is worth reflecting for a moment on the attendant changes which have been introduced by this rapid development. One change that might have been expected, a diminishing number of Arts students, has not been conspicuous at Oxford. Although the Science student is needed by industry and by the Government, although he can look forward to a secure post even without a First Class degree, although Science is subsidised by the State—in spite of all this, the students of History, Modern Languages, even of Classics, remain surprisingly steady. This, I imagine, is far less true of the modern Universities, and Oxford on the Arts side is perhaps flourishing at the expense of her younger brothers and sisters. At any rate in Oxford there is still the right mixture of Arts and Sciences to provide a background for that wider informal education, which is conducted by discussion and by living together in a College.

However, it is certainly true that the development of Science has been a centralising force, a force that pulls against the preponderating influence of the College. The young Scientist no longer works mainly within his College. In the old days, Colleges often had their own laboratories, but clearly they could not meet the new demands of individual Sciences, and now the student spends a great part of his working-day in a University laboratory, consorting with fellow students in his own subject. There is little danger now that the College could exert too strong an influence, as it may have done in previous generations. Economically and educationally, the University is coming into its own again, with the rapid development of Science. All the more important, therefore, that the closer and more intimate life of the College should continue to exert its effect on Science student and Arts student alike.

I said just now that the University had come into its own economically as against the Colleges. Oxford, like other Universities, receives large subsidies from public funds. There were at first many voices raised against such an innovation: the independence of Oxford was threatened and 'those who paid the piper would soon be calling the tune.' (And in these days of State control, it is easy to forget just how great was the freedom of University and College from outside control. The Head of one wealthy College entirely refused to admit the members of a nineteenth-century commission within his walls.) *Prima facie*, the receipt of State money has not brought State control, and Oxford is still largely free to spend as it likes, not only its own wealth but the Treasury's subvention. I say *prima facie* because, from a wider aspect, it is possible to see the effect of public demands on University education in ways of which most of us are surprisingly unconscious. We accept these demands as normal and justified, and fail to realise that in fact they are substituting a different educational ideal from that which our fathers and grandfathers took for granted.

This ideal was admittedly limited in its range of application; for centuries it was an ideal only for the privileged few. But for them it set up a fine and liberal standard. We may call it vaguely the ideal of Christian Humanism: it combined, with varying emphasis at different times, the Christian view of every child as potentially a child of God; the desire for knowledge and beauty for their own sake, a view taken ultimately from Athens and re-interpreted at the Renaissance, and a practical sense of justice and of the art of ruling, which came from ancient Rome. It was an ideal down the centuries which shone and faded and shone again. The point for our consideration here is that it was an ideal dictated by the character of the individual: his calling would be decided by his gifts and his natural endowments, and his schooling must enable him to make the most of them. To this ideal we still pay lip-service, but, under the phrase 'education for the community,' are we in fact admitting tacitly quite a different ideal, viz. that the schools and Universities exist to supply the community with men trained as the community requires and in just the proportions needed from time to time?

Perhaps this *is* what the modern world is bound to demand of its educational system; certainly we educationists acquiesce in such demands. We are told, let us say, 'There is still room for biochemists. You should train more biochemists. Why is not Oxford making its

full contribution to bio-chemistry ? ' The interesting thing is that so many of us humbly accept the criticism and feel that we really must do better in our production of bio-chemists and induce more students to take it as their main course. There may be nothing wrong in this ; but at least we ought to observe that such an assumption is quietly changing the old educational ideal of the man educated to make the most of himself along his own best line. At its worst this ' education for the community ' may lead to directed education (as is bound to be the case with soldiers in war-time) where the State dictates the whole syllabus with an eye on its own immediate needs. We are still far from that position in England, but we have diverged sufficiently from the old ideal to make many classic statements of educational aims sound strangely irrelevant to-day.

You would not, incidentally, find the blessed word *Research* mentioned in old-fashioned essays on the functions of a University, and I may interpose a word here on the immense development of Research in all Universities, and especially for the postgraduate student. The number of postgraduate students at every College has, I imagine, increased by five-fold since I was an undergraduate. This development is due of course primarily to the ramification of Science, and industry's increasing demand for it, and in that there is nothing to be deplored. Research is the life-blood of Science : and an ancient University, like any other, must take the demand into account. Research has an immediate effect on the practical uses of Science, though every student of the history of Science knows that many far-reaching discoveries have not been made by men who set out to solve a particular problem or confer a particular benefit, but by those who pursued their inquiries in a spirit of pure curiosity, true to the principle that a University can never afford to lose sight of ' knowledge for its own sake ' as one of its ideals. But the spirit of Research has spread to other subjects, and it is possible to ask whether Oxford has not gone too far in its efforts to keep up with the times in encouraging second-rate Research in Arts subjects. Such Research is not always educative : is it really enlarging the boundaries of knowledge ? The researchers claim that you cannot build a house without bricks : I wonder sometimes whether the bricks which they laboriously gather are destined, not for a house, but a brick-heap ! There is of course always room for the *first-rate* researcher : but when the average young man comes to me asking for a fourth year at Oxford to research into an author whom he had scarcely heard of till his tutor mentioned his name, I am reminded of the wise-crack : ' to copy from one book is cheating ; to copy from two is research.' In this respect, an ancient University ought not to follow the fashion too readily.

Such would be the view of what we may call the University idealists—like Dr. Hutchins of Chicago : and their warning is salutary. But in their championship of pure and ' useless ' knowledge, they go too far. They would claim, and there are some in this country to follow them, that an ancient University like Oxford has become too technical and too vocational. The two epithets are frequently used together in educational literature as if they were almost interchangeable ; of course they are not. Technical education involves the learning of a specific technique or craft, and all scientific education must be technical to a more or less degree. The question is whether the acquisition of a technique is an end in itself or a stage in acquiring new knowledge, to which the technique is only a means. If it is the first, the proper place for it is a Technical Institute. Scientific training for the average student *may* be no more than acquiring a technique. This is a standing danger at a University : and the remedy lies not so much in modifying the training but in ensuring that the teacher himself is not just a technologist, but one who is able to see means and ends in proper proportion and perspective.

The risk that a University should become too technological, with a stultifying effect on the minds of the pupils, is one that applies mainly to the Scientific faculty. When a University is accused of being ' too vocational,' all faculties are involved. There is undoubtedly a danger here of which a University must take note, and one can see what the critics have in their minds. But here too some of them overstate their

case. They speak as though only in materialist modern times has a University become vocational. But from the earliest times Oxford prepared young men for the Law, the Church and for Medicine. And still a University is bound to be vocational in this one respect if in no other : it must train some of the students to recruit its own ranks as University teachers. No doubt in the eighteenth and nineteenth centuries when a University was confined to a small privileged class, there was little in the education which could be called vocational, unless it is a vocation to lead a life of leisured culture on an inherited income. Would the idealists like us to return to that standard? No : but nevertheless the standard implied in the abused word ' culture ' must not wholly disappear. To the ordinary man, the reader of the cheaper daily newspaper, for example, there is no *danger* in a University becoming vocational : as far as he thinks about a University at all, he regards it as a superior institution for getting better-paid jobs for its members—a kind of superior high school. I once heard a parent speak of a grammar school as a ' place where you get the School Certificate from.' Similarly the University would be ' a place where you get a degree from.' In many Eastern countries it is, alas, regarded in just this light. The result is that everyone wanting a Government job—which means a large percentage of the educated class—presses into a University. The numbers swell and swell : the classes become more and more unmanageable, the education more stereotyped and less satisfying. The product is not an educated man, not even a man able to get a Government job, because, as one may imagine, there are not nearly enough jobs to go round. The more effective part of a student's education is the extra-curricular part, education in student-politics—the tactics of strikes, the best way to challenge authority. (I am thinking of what I saw during seven months in the East.) This sort of education added to a high rate of unemployment is a difficult mixture for any country to digest. And one cause of it is the view of a University as solely vocational. It is by no means confined to Science students : it extends equally, or even more, to the faculties such as Law or Economics. When I returned last year from India to Oxford, I asked myself why our undergraduates, quite as full of spirit and youthful ideals, were not, as students, preoccupied with politics—University or national. No doubt the English temperament and the absence of grinding poverty are partly responsible. But one reason surely is that education at our Universities is not solely vocational, not just a means to an end, but sufficiently interesting in itself to satisfy the active questing mind of a young man, and he has less need to look for excitement in other quarters. The ideal of a strictly ' non-vocational ' University cannot to-day by itself be sufficient for Oxford, even as an ideal (and one may doubt if it ever was so), but it must remain one element in the ideal : knowledge for its own sake, culture, education for leisure, and civilised intercourse—these are precious parts of our heritage and perhaps an ancient University has a special responsibility to preserve them.

But it can only do so, if the young men themselves arrive at a University with a background of sufficient general education to understand that knowledge *can* be pursued for its own sake, and is not mere material for examinations. I myself have taught classical students, well-crammed for their scholarships, who seemed to think that if they did not get a First, then Virgil lived in vain. A boy may have advanced far along the road of his own speciality, and yet have little idea of its relation to other branches of knowledge or to civilisation, and have no wish to make the necessary co-ordination in his own mind. At the newest of our Universities, Lord Lindsay, the founder of Stoke, was keenly alive to such a danger, and laid great stress on two things : 1. The preliminary year of general education, and 2. The residential quality of the University : for he knew from Oxford how much of education depends not on the lecture room but on the common life. Is there implicit here some measure of criticism of an ancient University? The shared life we have always had : but are we too ready to allow young men of limited background and narrowly specialised education to continue along the same groove, and thus to endanger their best and earliest

opportunity to 'see life steadily, and see it whole'?

In the old days at Oxford and Cambridge, though there was much idleness, much aimlessness, and much self-indulgence, the young men who did any work at all, at least approached it with some half-conscious sense of humanistic values and the unity of knowledge: they brought it with them, not usually from their schools, but from their homes, with history all about them, in buildings or pictures, homes with books on the shelves and good talk at the table; homes that observed the seasons in the fields and at the church. I should never be in favour of a return to such days, even though such a return were possible which it is not. The older Universities then produced, like the Public Schools which largely fed them, eminent and able men; but, again like the Public Schools, they took the credit of producing rulers, who would in fact have ruled by virtue of class, apart from their education. There was a host of Victorian writers, artists and reformers who owed nothing whatever to a University and had a more abiding influence than the statesmen. In those days the smaller, less famous Colleges were sometimes half empty: the University was far from working at 100 per cent. efficiency. To-day, the picture has completely changed.

And this brings me to the second great adjustment which an ancient University has had to make—and is making—to keep up with modern conditions. It is primarily a social and economic change, though it has its effects on academic education. Within my own lifetime, the two ancient Universities were regarded as the properly succeeding stage to the Public Schools. Not all Public School boys entered the University, but those that did, set the dominating tone. The fees of Public School and University alike were far beyond the range of any but 2 or 3 per cent. of the population. There were of course brilliant boys who paved a road for themselves with scholarships: they were still the exception. On the whole, it would have been said, the older Universities and the Public Schools drew on the same privileged well-to-do class, and would sink or swim together. That would have been the forecast in, say, 1910. How mistaken it has proved! The Public Schools are still dependent on the private means of parents, now in prosperity and now in depression, with no prospect of state-aid. Educationally, I am convinced, they have made a steady advance: but economically can they hope to continue as they are, when parents are already paying out capital to meet the fees? But Oxford and Cambridge have never in their whole history been as prosperous as they are to-day, if prosperity is measured by the number of applications for entry. At the College I know best over five hundred applications were received in the single year 1953. No doubt some of these applicants asked for admission elsewhere too. But in any one year we could have had a hundred and fifty candidates sitting for admission for some forty-five places as commoners: for the figure I have given excludes scholarship candidates who take a different, more competitive examination. My only object in mentioning these rough figures is to show that all Colleges at the ancient Universities reject annually a number of young men who appear well-qualified for entry, simply because there is no room for them. At each of the five women's Colleges in Oxford three or four hundred girls every year are actually examined at their Schools; about a fifth of that number interviewed and the successful candidates drawn after scrutiny from among those who gain an interview. As is well known, the great majority of these young men and women come up to the University on public money: and no doubt they must live carefully and many work in the vacation. (On that vexed question may I say in parenthesis about vacation work that, in my experience, the best boys *can* combine vacation work with academic study, though others are ready to give vacation work as an excuse for academic deficiency, provided you do not inquire too closely what they did in their vacation while they were *not* working!) They must as I say live without extravagance, and there are of course temptations to be extravagant: but I recall what an old member of Jesus College said to me who had come up fifty years ago on an exiguous emolument: 'These lads do not know what it means to be really poor.' If that is true, all the better: there is a

poverty which stimulates, but there is also a poverty which can isolate. At any rate here the boys are (State Scholars or locally assisted, most of them), in far greater numbers than ever before in Oxford. Their presence represents the greatest adjustment to modern conditions which an ancient University has had to make. Compared to the Oxford of forty years ago, there is some loss : but there is far more gain. I have known Oxford intimately at three different periods : as an undergraduate in the early 1920's, as a young don in the early 30's, and as the head of a College in the 50's. Of the three, the Oxford of the 1950's seems to me the healthiest and the best accommodated to the needs of the time.

The development of this social adjustment has been, like so many processes at Oxford, largely unconscious. At no one stage did the University say ' let us now be more democratic.' But the change would never have come about if the voice of the traditional ruling class had been the true voice of the University. If heads of Colleges before the first war had carefully discriminated man from man, according to accent and manner and social agility, then Oxford might well have been left high and dry, with what is vulgarly termed ' snob-value,' but without the true educational value that has impressed itself even on the Treasury and the Ministry of Education. As it is, she is assisted up to the hilt by the State, to keep her registers full and her laboratories up to date. We owe a debt that may easily be forgotten to those far-seeing men at the beginning of this century who determined to throw the gates of Oxford wider and wider open to all who could profit by an Oxford education. As a consequence, the Oxford of to-day is more representative of the whole community and more homogeneous in itself. The clear-cut social distinctions between Colleges, so common once and so apt to breed unconscious arrogance and hidden resentment, are breaking down : on the exclusively social level of the dance and the dining club they still exist. But these are in fact less important than the College discussion group, the Oxford Union, the river and the playing-fields : here the social levels and the different ' income-groups ' mix freely, with the great benefit on both sides of the dividing line. Perhaps Oxford has no right to take the credit for this trend : she is only reflecting a tendency seen throughout the country : perhaps, ultimately, any University reflects the social ideals of its age. But at least she is not hanging back : she is not championing the lost cause of the inherited income and the life of ease. Naturally the preponderance of the State Scholars (in the widest sense) presents the University with a new problem.

For most of these young men, Oxford is not the top-dressing—the very pleasant top-dressing—on a plant nurtured in a leisured home, an expensive preparatory school and an ancient, beautiful and rather Spartan Public School. They must acquire in their own way, from three years at Oxford, what earlier generations had absorbed in twenty. And very well most of them set about it. Some of them work too hard, or at least take their work and their examinations in too grave a spirit. I can fully understand the reason for that, and I appreciate their conscientious ambitions. But they are not getting the most from their University. Last year for the first time, in addressing Freshmen, I warned them (with, I hope, suitable qualifications) not to work too hard. When I thought of the extreme improbability of my old President at Trinity addressing such a warning to me in 1919, I felt that Oxford was indeed adjusting itself to new conditions ! Most of these young men, I hope, are learning, and will learn, to combine, during their three or four years, the foreground with the background of their Oxford life : their immediate task with the age-old traditions of an ancient seat of youth and of learning. Oxford herself, in adapting her ways to new demands, has in many cases broken new ground : in coping with the spread of Science, with an increasingly complex organisation, with the requirements of a University Grants Committee. But in providing a suitable education for what was called long ago ' the poor scholar,' she is only going back to the ideals professed by many of those who founded her Colleges. By ceasing to be class-conscious and exclusive, she has been true to her tradition.

What my audience was expecting from

this paper I cannot tell : I trust they did not pitch their hopes high. I am well aware that much has been omitted, that no very startling conclusions have been reached, and no bold prophecies thrown out. The disjointed observations I have made are at least based on personal experience, and are, I expect, open to question. But it has ever been the Oxford system not to look for truth in the pupil's essay, but in the discussion which follows it. Oxford ' is not so ancient as she was,' but she is Oxford still, and I am proud to speak as her representative.

GENETICS AND THE ADVANCEMENT OF SCIENCE

At the Oxford Meeting of the British Association Section D (Zoology) and Section K (Botany) devoted Monday, September 6, to a joint session on genetics and the advancement of science. Papers by Professor S. C. Harland, F.R.S., University of Manchester, on *Genetics and Plant Breeding*, and by Professor L. S. Penrose, F.R.S., The Galton Laboratory, University College, London, on *Genetics and Medicine* are printed below.

Other invited contributions were presented by Professor J. Heslop Harrison, The Queen's University, Belfast, on *Genetics and Taxonomy* ; by Professor K. Mather, F.R.S., Birmingham University, on *Genetics and Biometry* ; by Dr. E. B. Ford, F.R.S., on *Genetics and Natural Selection* ; by Dr. A. Robertson, Institute of Animal Genetics, on *Genetics and Animal Breeding* ; by Dr. D. Lewis, John Innes Horticultural Institution, on *Genetics and Physiology* ; by Dr. G. Pontecorvo and Dr. J. A. Roper, Glasgow University, on *Genetics and Microbiology* ; and by Professor C. D. Darlington, F.R.S., University of Oxford, on *Genetics and the Advancement of Science.*

Plant Breeding and Genetics

by

Prof. S. C. Harland, F.R.S.

Until quite recently plant breeding was an art ; an art empirical and immensely effective, bound up with superstition and folk-lore but with rules of craftsmanship on the whole valid and derived, even though remotely, from biology.

The changes wrought by plant breeders have been very great. We have only to compare modern fruits, flowers and vegetables with their wild ancestors to realise how great they have been. In Central Asia one may see the wild melon, bitter in flavour, and no larger than a tennis ball. Near by is the large and luscious garden type, and scattered around are a series of transitional forms connecting the wild with the cultivated by imperceptible gradations. In the high Andes, the prototypes of our cultivated potatoes—no bigger than walnuts—are found among rock piles at the edges of fields, and close at hand may be seen the cultivated potatoes with tubers up to one pound or more in weight.

The changes which have taken place are both qualitative and quantitative. The Japanese radish can weigh as much as 40 lbs. Tobacco can be bred with practically no nicotine. Many fruits have progressed from the edible to the eatable. The poisonous lupin has been converted into a first-rate food plant by the elimination of its toxic alkaloid.

All these changes are useful changes, and the task of the plant breeder is to produce changes in plants to make them more acceptable to man. The basic technique of the plant breeder is that of selection acting on variability. Hybridisation is used as a method of increasing variability and for combining the good qualities of different strains. It is perfectly possible to breed plants using these techniques without any knowledge of the genetical aspects of the material and still attain very great success. The modern cauliflower owes nothing to genetics.

Plant breeding has been carried out since the dawn of civilisation, first by peoples engaged in primitive agriculture, and certain plants were found to respond to selection. In time, conscious selection of seeds from the best plants was made to grow the next generation, and this meant a change in gene frequency, some genetical combinations being favoured and others rejected.

Plants were selected for their phenotype,

on what they looked like, though this might have no relation to the quality of their offspring. It was hard for the plant breeder to realise that the characteristics of a progeny were the important thing and not the appearance of the parent. Animal breeders found this out quicker than plant breeders. Race-horse breeders have known for a very long time that all winners of classic races do not make good sires, and since a lot of money is sunk in the sire they do appreciate as the plant breeder in the past has hardly ever done, that the breeding quality of a sire is to be judged by the quality of his 'get'—that is by his genotype. Towards the close of the seventeenth century Camerarius discovered sex in plants. The function of the pollen as the male fertilising element soon became known and in 1708 Thomas Fairchild made the first artificial plant hybrid by crossing the Sweet William and the Carnation. This was known as Fairchild's Mule and is to be found in the herbarium of the Oxford Botany Department. It is as important in biology as the original Wright monoplane is in aeronautical science. It started something as important to man as the machine. It vastly increased the possibility of growing more food and better food, and I need hardly stress the point that because there is a limit to the maximum amount of food per acre and no limit to the *population per acre* we may yet find ourselves starving in the midst of technological perfection. With hybridisation added to selection as a weapon the plant breeder could now try to unite in a single strain the good qualities of several. He could for example try to combine the hardiness of Yorkshire Hero with the resistance to water-logging of Lancashire Wonder, and he could still do this without a knowledge of genetics. And this sort of possibility has led many into a profound scepticism regarding the value of genetics to the plant breeder, and the idea that genetics can help the plant breeder has frequently, in the words of Uncle Remus, 'Set up a monstus gigglement.' The advent of the 'Phrase crammed' graduate into the field of plant breeding has not helped genetics in its attempt to guide the empirical plant breeder, who does at any rate know his material as a mother knows her child.

I will surmise that large numbers of plant breeders with conventional botanical training have embarked on a most turbulent and uncharted biological sea without ever having grown a plant, or hybridised one, and usually without any knowledge of genetics except that implied in the grand finale of that well-known limerick—one white, one black and two khaki.

And it is, therefore, not surprising that the successes of our plant breeders have rather been due to the accommodating nature of their material than to the employment of genetical ideas which might have helped them to get there sooner and get there quicker. The plant breeder has interfered with Nature. Some people object to this, but we do not find them eating wild instead of domesticated asparagus. To those who attribute all modern evils to man's interference with nature, we may admit that not only have we biologists interfered with nature by deciding what combinations of genes are to survive and multiply, but we intend to interfere still further in the future.

The whole of plant breeding has been a vast experiment in selection. But when you start an experiment to induce a given effect you may also bring about all sorts of other effects that were not in your mind when you began and which you would rather not have.

It is therefore my purpose to discuss some of the genetical implications of this selection experiment.

The wild type of a domesticated plant is constructed genetically of a series of harmoniously interlocking and balanced genetical systems to which the name modifier complexes or modifier constellations used to be applied, and to which more recently the name polygene system has been given.

Many years ago I used the phrase 'the modifiers constitute the species.' By this I meant that the constellations of genes of small effect acted together to produce a harmonious and adaptive interrelation with the environment and conferred on the species the power to occupy specific ecological niches.

The whole genic outfit reacts adaptively to a dynamic, fluctuating and oscillating environment and though polymorphic, can be envisaged primarily in terms of a

general main complex—what may be termed the vitality complex.

But in addition there are other important complexes—a reproductive complex, an anti-mutability complex and a complex which serves to buffer the species against nutritional deficiencies or imbalance. It must not be imagined that these are strictly separable from each other, or that their boundaries are definable in genetical terms, or that a gene may not be a member of the vitality complex and other complexes at the same time, just as an individual can be at the same time a mathematician, a Presbyterian and a vegetarian.

Let us first examine the effects of selection on the vitality complex. Selection acts as a process of extensive gene substitution which, having been made during domestication, has been of such magnitude as greatly to impair vitality. By making some rare genes common and common genes rare a highly domesticated plant is usually no longer capable of survival in a wild state. We may say that the vitality complex has been genetically eroded. This erosion is perhaps the commonest and most characteristic outcome of selection. From a horticultural standpoint this impairment of vitality, to which there are of course exceptions, does not matter a great deal, since we can theoretically provide an artificial environment for a physiologically changed domesticated product. We do not always know how to do this. It is the vogue to grow tomatoes in highly fertilised sterilised soil. Some varieties are physiologically maladapted to this novel environment, the reason being unknown.

Erosion of the vitality complex can be counteracted in three ways—(1) by prescribing and constructing appropriate environmental conditions. (2) By selecting new genotypes which will fit into whatever environment is practicable or theoretically capable of producing a larger crop, but practically unable to do so because of genetical limitations. A good example of this kind of change are the new short and stiff strawed wheats such as Atle which can stand up to heavy fertilisation and rainfall without lodging.

To sum up ; prolonged and extensive selection for associations of characters not possessed by the wild type usually reduces vitality, and new environments are necessary for the modified genotypes. Study of genotype and environment should be closely associated and this means that the tools of both genetics and physiology are almost equally important to the plant breeder.

I come next to the reproductive complex for which the genes are obviously very numerous and precisely adjusted. Here again extensive gene substitution and other selection effects such as impaired physiological balance have quite frequently led to varying degrees of sterility by the same process of genetical erosion and examples are not hard to find.

They are common in some animals such as horses, cattle, dogs and Drosophila in which various types of sterility often present serious difficulties to the breeder. In plants they are most evident in those propagated vegetatively, in which parts other than seeds have been the object of selection. Many varieties of potato in Europe do not fruit, though in the Peruvian Andes seeds are abundantly produced in practically all varieties. It is quite important not to reduce unduly the reproductive capacity of even vegetatively reproduced plants. In plants reproduced exclusively from seeds the capacity to produce seeds has only been impaired in certain environments, since seedsmen must live. The modern sweet pea has been so selected for size of flower, number of flowers per stem and ability to exhibit giantism under luxury nutrition that it hardly seeds at all in many localities, though in the same conditions the older varieties of the early 1900's seed quite freely. It is not known how far abundant seed production can be reconciled with exhibition giantism. Finally attention may be directed to the frequency of the phrases ' shy-seeder,' or ' shy-bearer ' appearing in horticultural literature. The third of these complexes is the anti-mutability complex. Observations coming from a variety of sources have led to the idea that the general mutation rate of a species is to some degree a function of genetical constitution. It is clear in Gossypium for instance that not only is mutation rate greatly increased in species crosses but that some genes cannot be transferred from one species to another because they mutate to the recessive more and more frequently in

successive backcrosses. It may be postulated that the wild type of a species has a general mutation rate controlled by a similar complex to the vitality complex and that when extensive gene substitution takes place it involves the replacement of anti-mutative genes by their alleles. We may thus expect the mutation rate to increase *pari passu* with the degree of domestication and on this count highly domesticated species should be more mutable than their wild progenitors.

If selection erodes the anti-mutability system it is clearly profitable to try to increase the rate of mutation, especially when the amount of natural variability is insufficient. Some degree of erosion of the anti-mutability complex therefore seems to be desirable.

There is no time for me to discuss other types of genetical erosion and I shall sum up by saying that all these considerations support the simple hypothesis that extensive gene substitution favouring the development of any one system will to some degree impair the efficiency of other systems. I have termed this process genetical erosion.

Having examined the genetical implications of selection effects as a guide to future policy I want to examine the influence of different breeding systems on methodology. The plant breeder is concerned with two main breeding systems, an outbreeding one such as that possessed by maize or clover and an inbreeding one illustrated by wheat and peas. Between these are to be found numerous gradations. In its native home the tomato is out-crossed to the extent of 30 per cent. or more as also in some regions is cotton. Inbreeding depression and its corollary hybrid vigour are characteristic of the outcrossed species and in the intermediates is roughly proportional to the degree of out-breeding found in nature.

It is not however appreciated that material taken from different parts of the geographical range of a species may show wide variation in the degree of inbreeding depression and consequently in the appropriateness of the inbred material for the commercial exploitation of hybrid vigour.

For example inbreeding of the native maize of Trinidad was frequently accompanied by hardly any depression in vigour in four generations, by which time uniformity was established at a high level of vigour. Though this behaviour is at variance with experience in North America the explanation seems fairly clear. It is common in the West Indies for small patches of maize to be grown from a single selected ear. This constitutes a mild degree of inbreeding over many generations and a gradual change in the breeding system whereby selection now operates on loci predominantly homozygous, instead of heterozygous—the normal situation in large populations of out-bred species. In such species fitness and vigour depend on harmonious associations or systems of heterozygous loci and indeed on the advantage of heterozygous phases of genes over homozygous phases. It ought therefore to be possible to substitute by extremely slow fixation a new homozygous system which will suffer little if at all from inbreeding depression. It is probable that in such plants as Brussels sprouts the relative lack of inbreeding depression is related to size of population in previous generations.

I have tried to show in very condensed fashion the genetical implications of the selection effects produced by the labours of successive generations of empirical plant breeders. It is abundantly evident in many parts of the world that it is highly dangerous to entrust selection to workers unaware of the genetical implications of what they are doing.

Plant breeding has not yet ceased to be an art and the plant breeder who loves his material and lives with it night and day still plays a most important part. Long may he live, crossing the best with the best and hoping for the best.

But many of our urgent plant breeding problems are beyond his capacity. For example to produce disease resistant varieties requires a knowledge of the genetics of the host, the genetics of the parasite and the complicated interaction between them from both the physiological and the biochemical points of view. Plant breeding is evolving into a new science of genetical engineering, and it is the business of both plant breeders and geneticists to meet on common ground for the advantage of both.

Genetics and Medicine

by

Prof. L. S. Penrose, F.R.S.

Introduction

The study of heredity as a cause of disease dates from early times. Indeed, the formal pattern of inheritance of several rare diseases was recognised in man long before formal genetics in experimental animals and plants was intensively studied. The type of inheritance subsequently described as ' dominant ' was demonstrated in the regular transmission of Huntington's chorea from parent to a proportion of the offspring. The type subsequently described as ' recessive ' had been observed in deaf-mutism early in the nineteenth century. Before this time the transmission of haemophilia through unaffected females to their sons had received considerable attention though the explanation did not come until 1912.

The systematic interpretation of pedigrees of human variations in terms of Mendelian concepts began soon after 1900. The recessive biochemical mutant, alkaptonuria, studied by Garrod (1902), showed the pattern of inheritance, which is now recognised as applying to an enormous number of defects both in man and in lower forms of life. In the case of alkaptonuria the defect is extremely rare and practically harmless. In many, much commoner, instances, however, the recessive type causes severe disease, which leads to death in infancy and can be classified as lethal. The heterozygote can show slight signs of the disease, or a defect arising later on in life. More usually, the heteroxygote cannot be distinguished from the normal by the techniques at present at our disposal.

The other common typical kind of single gene effect occurs when the heterozygote is recognised as abnormal in some way (e.g. ectrodactyly, Huntington's chorea) but for which the homozygous type is unknown. The homozygote is believed to be a severer form of the same disease and often lethal, in such cases.

Aims of Medical Genetics

Until recently the function of genetics in medicine was conceived to be the identification of as many as possible of hereditary traits and advice to prospective parents on the chances of the occurrence of this or that defect in the offspring.

This aim is becoming modified into a more dynamic approach by a variety of new findings. One of these is the discovery of so many hereditary biochemical peculiarities which affect health and disease in all manner of subtle ways. Another is recognition that, for most common diseases, the genetical background is complex, in that more than one gene enters significantly into the causation. Furthermore, there is growing knowledge of the interaction between heredity and environment. This has led to the successful application of medical science to the correction of hereditary disabilities. For example, in so far as diabetes or myopia are inherited they are cases in point. The surgical cures of retinoblastoma and intestinal polyposis are even more dramatic. The application of hygiene alters biological fitness. It is thus natural to ask questions about the effects of medicine upon the genetical structure of the human population.

The Supposed Increase of ' Bad ' Genes in the Population, due to Medical Science

A large body of opinion, both popular and scientific, regards these developments with suspicion and alarm. The ' bad ' genes, recognised as the causes of disease, are not being eliminated by medical science but, it seems, even positively encouraged by the attention and care paid to those patients who carry them.

The attempt to classify certain genes as ' bad ' and to aim at exterminating them from the human stock or reducing their incidence to a minimum is based upon a theory of attractive simplicity. The carrier of a ' bad ' gene, even if he is not himself diseased, must be discouraged or prevented from reproduction. The carriers of ' good ' genes are, correspondingly, to be encouraged. This is the basis of eugenic policy.

According to many very eminent authorities, the aims of medical science are fundamentally opposed to the aims of eugenics. The consequence of applying the principles of modern sanitation and public health, controlling infection and improving diet, is that weaklings of all

kinds are helped to survive. As Pearson (1912) expressed it, ' we have suspended Nature's effective but oft-times harsh methods of raising our stock.' According to Muller (1950), ' The improvement in living conditions, medicine, etc., under our modern civilisation, must result in a saving for reproduction . . . of a large proportion of those who, under earlier conditions, would have been genetically proscribed. . . .' In the long run, a state of biological chaos will develop in the human race. Such predictions are continually made by serious thinkers and also by writers explaining science to the public. Huxley (1951) goes further and states that, in almost all the industrially and socially advanced countries, the level of innate intelligence, and probably of other desirable genetic qualities, is decreasing generation by generation. Cook (1951) has questioned whether the great men of medical science, Jenner, Pasteur, Lister, Koch, have really been benefactors. The only hope, according to Muller, is ' the coupling of ameliorative techniques with rationally directed guidance of reproduction.' The crucial point in this suggestion is the definition of ' rationally directed guidance.' This can vary between tentative medical advice and compulsory sterilisation or even euthanasia.

The idea that genetical decay of the population is brought about by civilisation has been in the minds of people for a long time. Galton (1869), the founder of eugenics, deplored the tendency for eminent men to have few children. In recent years much has been written on the expected decline of intelligence resulting from differential fertility. The school children who do best on intelligence tests come from smaller families : those who do worst come from larger families. This inequality is thought to be exaggerated, if not actually caused, by social and medical services.

' Bad ' mutant Genes

The genetical hypothesis, on which all these arguments are founded, is, again, simple and consistent. Fresh mutations of unfavourable genes are continually occurring and, in natural surroundings, such genes will be eliminated (rapidly, if dominant and slowly, if recessive) by natural selection. In either form—heterozygous dominant or homozygous recessive—mutant genes are bad, as Ford (1952) expresses it, their effects are ' evil.' They only persist in the population by virtue of a balance between mutation rate of the gene and reduced fitness of its possessor. By artificially increasing the fitness of the carriers of these genes we increase our ' load of mutations ' as Muller calls it.

If this is a true picture of the genetical background of disease, medicine and eugenics are indeed directly opposed to one another. Medicine, concerned with the health and happiness of the individual, does not seek to judge the biological fitness of the patient. Assessment of his contribution to the genes of future generations lies outside medical ethics.

Fortunately, in one very important clinical field, the conflict between medicine and eugenics hardly arises. This is the study of maternal and foetal antigens. The situation is, perhaps, unusual because the genes, concerned in the incompatibility of mother and foetus, are not themselves considered abnormal or ' bad.' They cause no haemolytic diseases unless they are in a particular configuration. Neither the *Rhesus* positive child nor the *Rhesus* negative mother is abnormal. There is no obvious advantage in trying to eliminate either type in favour of the other. The medical problem is straightforward ; it is to understand the genetics together with the process of immunisation and to learn how to counteract ill effects.

Heterozygous Advantage

There are, however, all the other genetically produced diseases which have to be considered. One idea, which I wish to discuss and to apply, concerns what has been variously termed heterosis, hybrid vigour, over-dominance, etc. This means simply that the heterozygote has an advantage over either homozygote. The special hypothesis is that, in wild populations (such as the human), heterozygotes are, as a rule, the fittest genotypes. That is to say, ' bad ' genes are not wholly bad. They can be ' good ' in certain circumstances and combinations. The usual situation is that, in the heterozygous form, the gene is sometimes slightly ' good ' although, in the homozygous form, it is ' bad.' Such genes

are, as it were, poisonous or toxic in strong dose but, like some drugs, useful in a properly controlled dose at the right time.

The remarkable genetical property of heterozygous advantage is that, in a randomly mating population, it produces stable equilibrium of gene frequency. This fact has been used by Fisher and Ford to explain certain types of polymorphism in natural populations but the recognition of its probable application to man has been slow. My own suggestion (Penrose, 1947) that the differential fertility with respect to intelligence might be an example of this type of genetical phenomenon, thus leading to stability, was met with the utmost incredulity. The point is, probably, that, whereas the idea was acceptable that a normal trait, like red hair, taste deficiency, or a special blood group, could be an example of balanced polymorphism in man, it was difficult to believe in the existence of balanced lethals. Nevertheless this is the idea that I have intended and still intend to exploit.

For a variety of reasons it may be supposed that those people, who are specially fertile and whose standards of living are low—the social problem group or submerged tenth of the population—are more often carriers of genes for deleterious or lethal recessive traits than are the rest of the population. Why not further suppose that the increased fertility of the people of low intellectual level is an example of heterozygous advantage? This produces genetical equilibrium and stability of intelligence level in the population even though there is much assortative mating. In the absence of inbreeding or assortative mating (like mating with like), only a very slight degree of advantage in the heterozygote is sufficient to balance an uncommon recessive lethal gene.

Example of the Sickle Cell Trait

Opposition to the hypothesis of balanced lethals in man has sprung very naturally from the comparative absence of known prototypes in experimental genetics. Recently, however, an excellent example has been accurately described in man. The sickle cell trait is present as a heterozygous condition in about 20 per cent. of native Africans. In its homozygous form, the gene is almost lethal, producing a severe anaemia. This is a typical biochemical mutant which produces an abnormal haemoglobin. The heterozygote (who possesses both normal and abnormal haemoglobins) has, however, an advantage in that he is almost immune to subtertian malaria, as proved recently by Allison (1954). In spite of the disadvantageous risk of anaemia, the total result, in primitive conditions of life, is a condition of genic equilibrium.

From the point of view of the present argument, this case is an example of what can happen to a typically ' bad ' gene when hygiene is introduced. In the absence of malarial infection, the advantage of the heterozygote disappears and, consequently, the gene frequency of the sickle cell trait will quite rapidly diminish. (This has actually occurred in the coloured population of the United States.) A desirable eugenic result (less hereditary anaemia) is achieved by control of a parasitic disease.

Environment producing Genetical Improvement

This encouraging finding suggests that it is reasonable to press the line of thought further. Let us suppose that most of the mutants we know in man carry an advantage in some or other circumstances. Many of the heterozygous genes for recessive diseases, with which the population is riddled (i.e. our load of mutations), may carry immunity to specific infective agents, like plague, typhus, typhoid, and so on. Otherwise they would not be so prevalent nor so unevenly distributed throughout the world. These infections are now being rapidly eliminated by medical science, so that the heterozygous advantage of this kind is withdrawn ; the gene frequencies will consequently diminish. Some biochemical mutants may be favoured in a different way ; their heterozygotes perhaps are better able to exist in conditions of famine or in peculiar climatic circumstances.

In general, it can be supposed that heterozygotes for most lethal or seriously disabling recessive traits are better off in primitive conditions than in a highly civilised community. They tolerate low standards of living, and breed rapidly, when exposed to infection, starvation,

discomfort, infestation and so on, perhaps because they are in some ways less sensitive than the ' normal ' homozygotes or wild type. When standards of living are raised these advantages of the heterozygotes tend to disappear. Hence, by consistently improving environment, we also improve the genetical structure of the population by reducing the number of lethal and sublethal genes. In so far as standard of living is equalised over the whole population, improvement of the quality is to be expected because the state of equilibrium will be shifted to a position of lower frequency, for what the eugenists regard as ' bad ' genes.

Direct evidence for such changes comes from the study of improved health, increased longevity, increased stature and intelligence of children, in all surveys undertaken in recent years in civilised countries. The usual interpretation is that, although health and physique are apparently improving, the population is genetically deteriorating. Personally, I see good reasons for accepting these improvements on their face value. While agreeing that environment is having a positive effect, there is no need to assume a latent genetical effect in the opposite sense. Actual genic changes could even play a small part in the measured improvement.

Throughout this discussion, I have assumed that the effects of hygiene on the abnormal homozygotes are negligible. It is found very difficult, in practice, to modify the effects of recessive lethal genes. If and when this becomes possible on a large scale, the present conclusions may need revision. We can, however, pursue the study of alleviation of hereditary disease without expecting to see seriously dysgenic results in future generations. We can even use bacterial genetics and the genetics of antibiotics as accessory studies with a good conscience. Medical science and hygiene benefit the abnormal, it is true, but they benefit the normal even more.

References

Allison, A. C. (1954), 'Notes on Sickle-cell Polymorphism, *Ann. hum. Genet., Lond.*, **19**, 39.

Cook, R. C. (1951), *Human Fertility*, London, Gollancz.

Ford, E. B. (1952), 'The Influence of Radiation on the Human Genotype,' *Biological Hazards of Atomic Energy*, Oxford, Clarendon Press.

Galton, F. (1869), *Hereditary Genius*, London, Macmillan.

Garrod, A. E. (1902), 'The Incidence of Akaptonuria,' *Lancet*, **2**, 1616.

Huxley, J. (1951), Introduction to *Human Fertility* by R. C. Cook.

Muller, H. J. (1950), 'Our Load of Mutations,' *Amer. J. hum. Genet.*, **2**, 111.

Pearson, K. (1912), 'Social Problems : their Treatment, Past, Present and Future,' *Questions of the Day and of the Fray*, **5**, London, Cambridge University Press.

Penrose, L. S. (1947), 'The Supposed Threat of Declining Intelligence,' *Amer. J. ment. Def.*, **53**, 114.

SEMI-CONDUCTORS, TRANSISTORS AND PHOTO-CELLS[1]

by

Dr. R. A. SMITH

Introduction

In Physics, as in most other human activities, there are fashions. Certain substances, known as semi-conductors, have suddenly risen to the front rank of importance. They were once a kind of Cinderella, hardly noticed beside their much more imposing sisters, metals and insulators. In recent years, a great deal of work has been done on the properties of metals but I am told that, at the moment, three times as many papers are written on semi-conductors as on metals. This greatly increased interest in semi-conductors has come about by a simultaneous appreciation of their significance in understanding the fundamental processes associated with the conduction of electricity in solids and of their very great practical importance. Neither cause by itself could have stimulated the very large amount of work now being carried out on these substances in university, industrial and government research laboratories in many countries.

We must therefore examine more closely the properties of this once despised class of substances. It is rather typical of the former attitude to these substances to say that they are poor conductors or poor insulators. Fundamentally they are nearer to the insulators in their properties than to the metals though their practical importance lies in their conduction of electricity. Indeed, at the absolute zero of temperature, a perfect semi-conductor would be a perfect insulator. We shall see how this comes about.

Typical semi-conductors in the form of elements are germanium and silicon; many exist as sulphides, selenides, etc., of which lead sulphide is typical. This is well known in its mineral form as galena. Recently the number of known semi-conductors has been greatly increased through the introduction of compounds which do not exist in mineral form. These new semi-conductors are mainly compounds of two metals such as indium antimonide and have some remarkable properties.

The first important practical use of semi-conductors was as crystal detectors in the early days of wireless but these were rapidly superseded by thermionic valves. Interest in them was re-awakened through the appreciation of their importance in illustrating some rather fundamental predictions of theories of the solid state proposed as one of the major developments of Quantum Mechanics.[2] They came into the limelight once more through their key role in the development of microwave receivers for radar during the war and again more recently as the basis of the solid electronic valve—the transistor. They have also played a vital part in the modern development of techniques for infra-red spectroscopy.

With the development of the transistor as a possible replacement of at least a substantial fraction of the vast number of valves in the form of vacuum tubes now in use, a very large industrial research effort has been turned to the study of these materials. It is fortunate that their fundamental properties have also been of great interest to the physicist so that there has been a happy combination of ideas from research scientists on the one hand and technologists on the other which has led to a rapid advance in our knowledge. These substances, it turns out, have many remarkable properties and enable us to study the fundamental processes of electronic

[1] Address delivered to Section A (Mathematics and Physics) on September 2, 1954, during the annual meeting of the British Association at Oxford.

[2] See A. H. Wilson, Proc. Roy. Soc. A, **133**, 458; **134**, 277, (1931).

conduction in solids more readily than with either metals or insulators. This is mainly because in them we can, to a large extent, control the number of carriers of electricity and can change this number to meet our needs, whereas in a metal we have a large fixed number of current carriers and in a good insulator we have hardly any. There are, moreover, a number of new phenomena of outstanding interest which have appeared, of which the transistor effect, which I shall discuss later, is perhaps the most spectacular.

Fundamental Properties of Semi-conductors

When atoms of matter are relatively free and unaffected by their neighbours, as in a gas, their electrons are fairly tightly bound to them and may be regarded as belonging to each individual atom, i.e. each carries its own electrons around with it and only rarely exchanges them with its neighbours. Electrons can, of course, be removed by collisions with free electrons as in electrical discharges, or by collisions with other atoms. The latter process happens very infrequently except at high temperatures when the individual atoms have, on the average, a lot of kinetic energy. When, however, the atoms are brought into close proximity as in a solid, we can no longer regard their electrons as belonging to individual atoms but are shared among neighbours. It is just this sharing that pulls the atoms together to form a solid and provides its binding energy. In an insulator the electrons may still to some extent be regarded as tied to individual atoms although this idea is shown to be inadequate when we use the quantum theory of solids. It is perhaps better to say that electrons may change places but in insulators seldom go wandering off on their own.

In a metal, on the other hand, when the atoms are brought together, one or sometimes two electrons from each atom detach themselves and go off wandering through the solid. On the average, their motion being random, no net current flows—just as there is no net flow of gas in a still atmosphere although the individual molecules of gas are dashing about at high speed. If, however, an electric field is applied a drift velocity is superimposed on the random motion of the electrons and a current flows. For a metal, the number of charged free carriers (electrons) is about equal to the number of atoms and is fixed for a given material. The variation in current when a field is applied then comes from the variation of their drift velocity.

In an insulator there are no ' conduction ' electrons as we call them, but there still are plenty of electrons there. Moreover, quantum theory shows that it is incorrect to say that any individual electron is attached to any given atom but can exchange its position with any other electron. It turns out, in this case, that the possible energy states which the electrons can *readily* occupy are all filled and so no electrons can be accelerated to move faster. This is a rather sophisticated idea but it is a bit like a road blocked by a too high density of traffic. There are plenty of cars but they cannot move because other ones are blocking the way ; only here we are thinking of ' energy space ' rather than of physical position in the solid. In an insulator all the available ' energy space ' readily accessible is filled and there is no room for manœuvre. The electrons in this position are said to occupy a ' full band.' It turns out that for electrons with considerably more energy there is also a conduction band in which the electrons can move freely as it is practically empty, but in an insulator it is separated from the full band by a large forbidden energy gap which no electrons can occupy. A metal may then be regarded as a road which is busy but in which there is plenty of room to move and an insulator as a completely blocked road due to a traffic jam. (See Fig. 1.) Nearby, at a somewhat higher level, is a completely empty road and if a car could be lifted up on to this road, i.e. given enough energy, it would be free to travel. Now just this process can occur occasionally. In the course of their jostling by the random thermal motion of the atoms an electron may be jerked by an unusually violent collision into the ' conduction band.' How frequently this happens depends on the amount of energy required, i.e. on the width of the forbidden energy gap. It also depends on the temperature—at higher temperatures the thermal motion of the atoms is more intense

and the probability of raising an electron to the conduction band is greater. When the forbidden energy gap is small this process will take place fairly frequently and an appreciable number of electrons will be ' raised to the conduction band.' The solid will then conduct. In this case we have a semi-conductor. A semi-conductor is therefore just an insulator with a small forbidden energy gap. Since the probability of stimulating an electron into the ' conduction band ' increases rapidly with temperature the number of carriers and hence the conductivity increase with temperature. This is a feature of semi-conductors. (For metals the conductivity decreases as the temperature is raised.)

As the temperature is lowered, in a semi-conductor, fewer and fewer electrons can make the jump to the conduction band, and finally as we approach the absolute zero of temperature no electrons will be found in the conduction band, all of them occupying the full band. The substance will then be an insulator as there are no free carriers to take part in conduction.

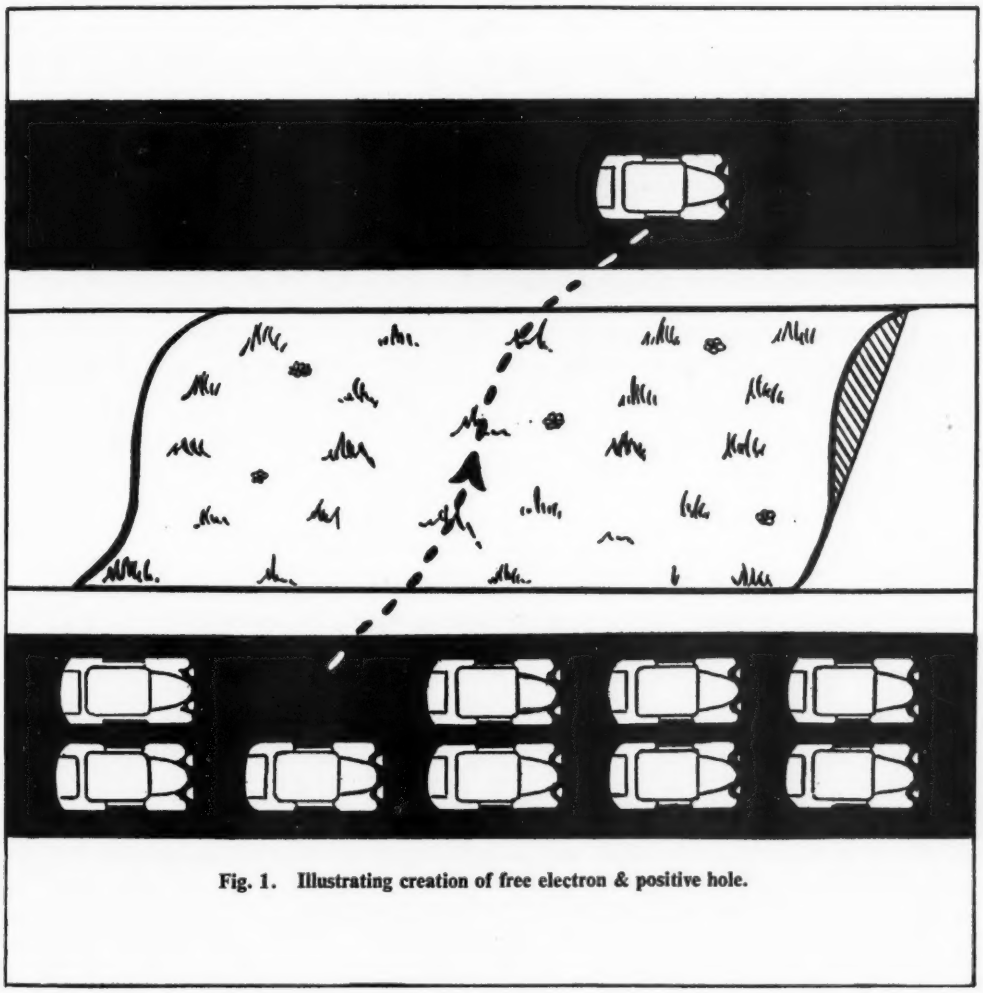


Fig. 1. Illustrating creation of free electron & positive hole.

Now we may note a very interesting thing can happen—a feature from which semi-conductors derive most of their importance. Let us return to our blocked road analogy. If a car is jumped up on to the higher level road it will create a hole in the traffic stream and other cars will be able to move up (see Fig. 1). The hole

will then move *back* along the traffic stream—but the net result will be a motion of traffic *forward*. In the same way a ' hole ' is created in the ' full band ' in the semi-conductor and since it moves in the opposite direction to an electron in an electric field it appears to carry a positive

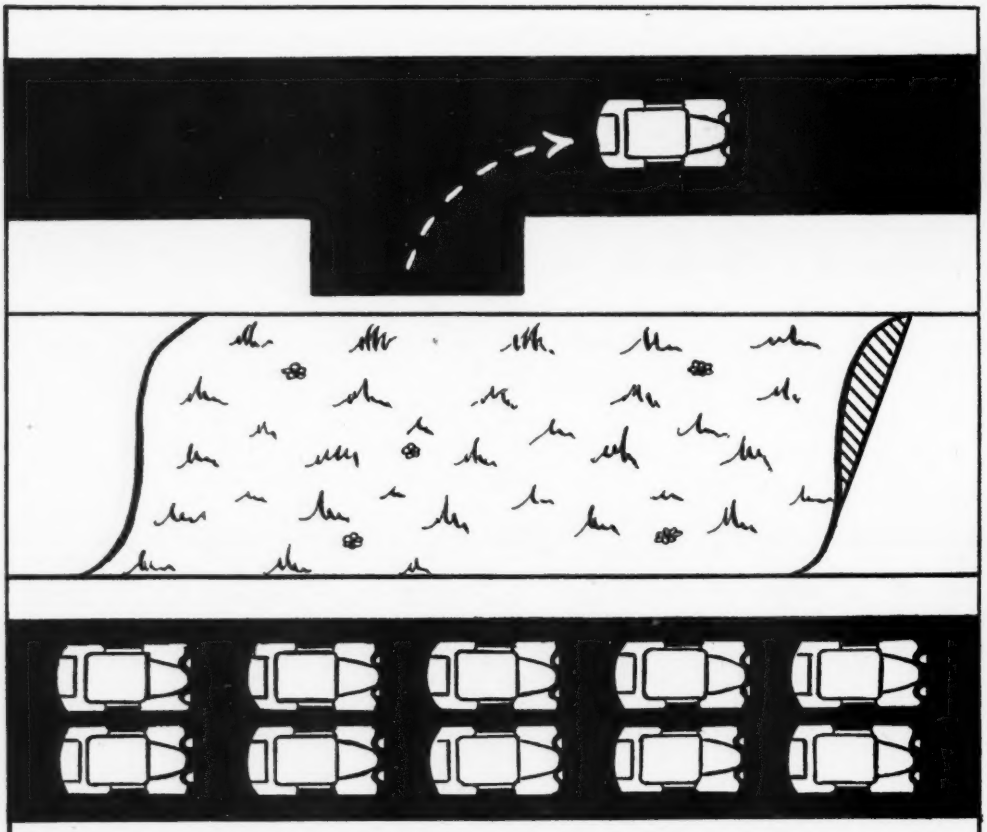


Fig. 2. Illustrating creation of free electron by donor centre.

charge ; it is known as a ' positive hole ' and behaves very like a positively charged particle. Thus in a semi-conductor current is not only carried by free electrons but also by positive holes. *In a perfect semi-conductor there are equal numbers of holes and electrons taking part in conduction.* The charge on each is the same in magnitude but of opposite sign—their ability to move through the crystal lattice, or ' mobility ' will in general be different and from our analogy with the cars we should expect the electrons to be more mobile than the holes. This turns out generally to be so.

Were this the whole story, semi-conductors would be much simpler but also much less interesting substances than they actually are. It appears that minute quantities of impurities may modify their properties very considerably. This can occur in two ways. An electron from an impurity may be very loosely bound and may be jostled into the conduction band very much more readily than an electron from the full band. This would be analogous to a car moving out from a ' lay-by ' near the level of the top road

(see Fig. 2). Again another type of impurity atom may readily accept an extra electron and this would create a hole. This would be analogous to an *empty* parking place taking a car from the lower full road (see Fig. 3). In either case only a single mobile carrier is produced. For example, let us consider what happens in germanium. Each atom has 4 outer electrons. Now if a germanium atom is replaced by an atom of phosphorus, which has five outer electrons, one of the extra electrons can be detached with very little energy and can wander off, i.e. go into the conduction band, the remaining four playing the same part as the four germanium electrons. If an atom of boron which has only 3 outer electrons goes in it takes up a fourth and creates a ' hole ' which can wander away. Thus there are two types of impurity known as n-type (for negative carrier) or donor impurities and p-type (for positive carrier) or acceptor impurities. If one or other predominates it will determine whether conduction is primarily by electrons or holes, creating an n-type or p-type semi-conductor. Except in the very purest material, impurity conduction predominates at ordinary temperatures. For example the number of ' intrinsic ' electrons or holes (i.e. arising from the pure semi-conductor) in germanium at room temperature is about 3×10^{13}/c.c. Now the number of atoms

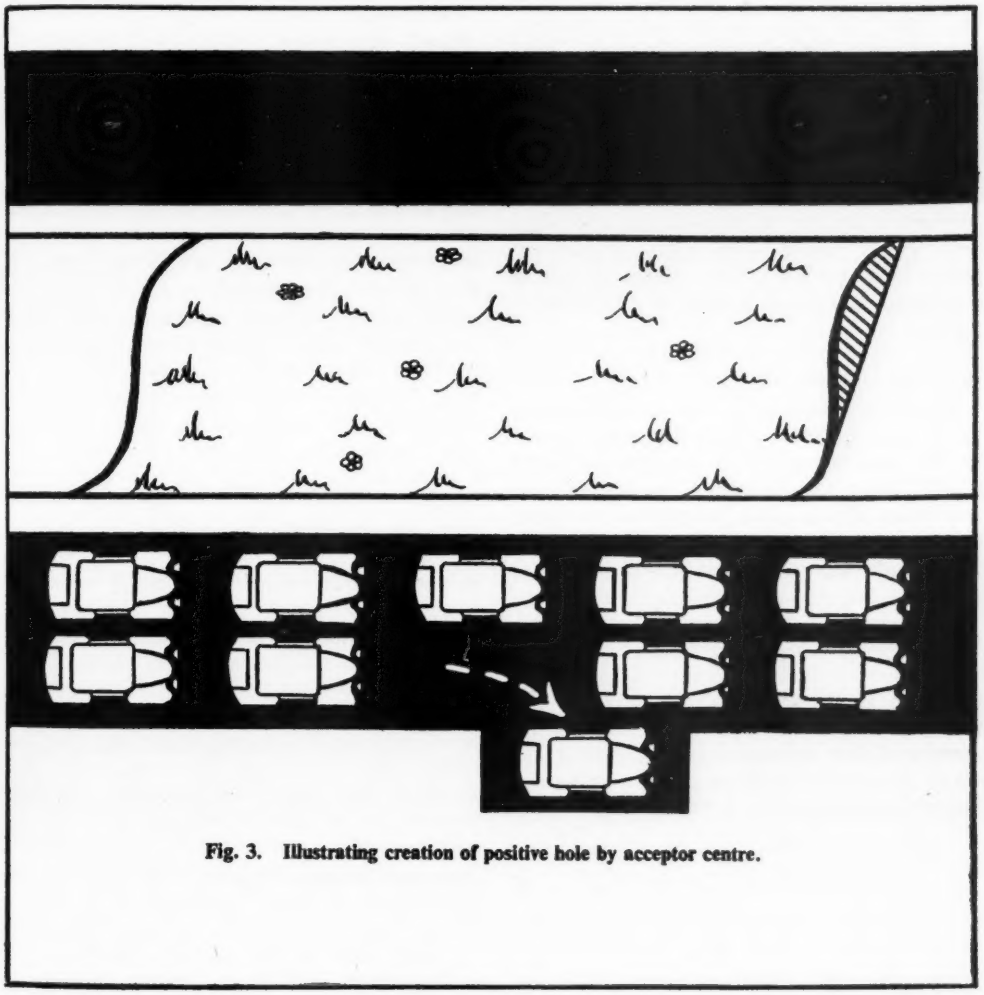


Fig. 3. Illustrating creation of positive hole by acceptor centre.

is about 5×10^{22}/c.c. so that only 1 free carrier exists for each 10^9 atoms. One part in 10^8 of an impurity producing electron would swamp the intrinsic carriers with impurity carriers. That germanium can now be produced in which the impurity content is such that the conductivity at room temperature is intrinsic (impurity less than 1 in 10^9) is a tribute to modern technology. Thus germanium is now perhaps the purest substance in the world.

Variation of Number of Carriers

Provided we start with a very pure semi-conductor the number of charged current carriers may be controlled by chemical means, by controlling the impurity content. Let us now see how, for a given sample of semi-conductor, this can be done by other means.

(a) Photo-conductivity

When light falls on a semi-conductor an electron may be raised from the full band to the conduction band by absorption of a quantum of radiation, provided the quantum has enough energy to perform the task. The energy E of a quantum corresponding to light of wavelength λ is given by the well-known relationship

$$E = \frac{hc}{\lambda} \quad . \ . \ . \quad (1)$$

where h is Planck's constant and c the velocity of light in free space. If all the energy of the quantum is absorbed by a single electron it will be able to cross the forbidden energy gap ΔE provided

$$\frac{hc}{\lambda} > \Delta E$$

or

$$\lambda < \frac{hc}{\Delta E} \quad . \ . \ . \quad (2)$$

Thus only light whose wavelength is less than a critical value λ_c will be able to perform this function. For insulators this critical wavelength lies in the visible spectrum or ultra-violet but for semi-conductors it lies in the infra-red. The values of ΔE at room temperature and the associated limiting wavelength λ_c are shown for a number of substances in Table I. The values of ΔE are measured in electron-volts and the wavelength in microns (10^{-4} cm.).

Table I

Substance	ΔE (electron volts)	λ_c (microns)
Diamond .	6.0	0·2
Silicon . .	1·1	1·1
Germanium .	0·75	1·6
Lead sulphide	0·3	4·0

The visible spectrum lies between $0{\cdot}42\mu$ and $0{\cdot}75\mu$, so that for the insulator diamond the critical wavelength lies well in the ultra-violet whereas for the semi-conductors Ge, Si, PbS it lies in the infra-red or region of heat rays. This is generally so. Thus when radiation having appreciable energy at wavelengths shorter than the critical value falls on a semi-conductor it raises electrons to the conduction band and, we may note, it also creates holes in the full band at the same time. In this way the number of holes and electrons in a given sample may be very considerably increased with consequent increase in the electrical conductivity. When the radiation is switched off the number will decay to the equilibrium value through recombination of holes and electrons. This it does in a characteristic time depending on the mean lifetime of hole-electron pairs. This increase of conductivity on illumination, called photo-conductivity, is of great practical importance, particularly when λ_c lies fairly well into the infra-red. It has enabled very sensitive photo-electric detectors to be developed for use out to wavelengths of about 8μ which includes a large and important part of heat radiation. The group of semi-conductors PbS, PbSe, PbTe have mainly been used as the basis of these detectors which take the form of a thin layer (about 1μ thick) deposited between two electrodes on a glass substrate. By suitable processing techniques, these layers may be made extraordinarily sensitive and show measurable changes of resistance for very minute amounts of infra-red radiation. In the range of wavelengths for which they operate they have now largely replaced thermal detectors like the bolometer and thermopile and have enabled spectroscopists to obtain much higher resolution than previously.

Also because they respond extremely rapidly to changes in radiation flux (in a few millionths of a second) they may be used with automatic scanning and recording techniques to obtain detailed spectra in a few seconds which previously took hours of laborious plotting to record. PbS cells have now been used for some time and are available commercially. The PbTe and PbSe cells, cooled with liquid air, are a more recent development.

(*b*) *Carrier injection*

When two metallic contacts are made to a semi-conductor and a voltage applied, a current will flow. In general, one would expect this current to be carried by the

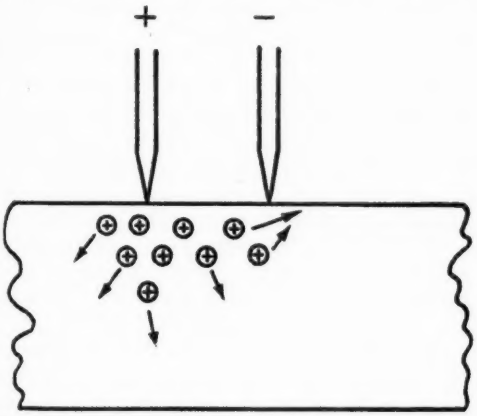


Fig. 4. Holes injected by a positive contact affecting current carried by nearby negative contact.

type of carrier which predominates. One of the most startling discoveries of recent years was, however, that this is not always so. For simplicity let us consider n-type germanium in which most of the current carriers are electrons. We shall suppose that these electrons are generated from impurity centres and that the number of holes generated thermally is relatively small. It is found that with some point contacts, when biassed positively with regard to the germanium, the current is carried mainly by *holes* and not by electrons, i.e. holes are injected into the germanium more readily than conduction electrons are sucked out. The hole concentration near the point can therefore be appreciably increased and this, as we shall see, is a basis of transistor action. Thus we have here another method of modifying the number and type of carriers in a semiconductor. This increased hole concentration has the effect of increasing the conductivity of the material in the neighbourhood of the contact. If now we have a second contact (see Fig. 4) near the first the presence of the holes will modify the current through it. If it is biassed negatively it will suck some of the holes out. Thus the current in one electrode may be modulated by the current in another—rather in the same way as the voltage on the anode of a triode valve may be modulated by varying the voltage on the grid. This formed the basis of the first solid triode or point contact transistor and it was the discovery of this phenomenon by Bardeen and Brattain in the Bell Telephone Laboratories in 1948 that led to the whole development of transistor physics.[1]

(*c*) *Carrier extraction*

By applying a strong electric field it might be thought that at least some of the current carriers would be swept out of a solid in the same way that they may be swept out of an ionised gas. A few moments thought shows, however, that for a metal at any rate this will not be possible. As electrons are swept out they leave behind fixed positive ions so that a space charge is rapidly created. This neutralises the electric field and the process stops. In an *intrinsic* semi-conductor, however, equal numbers of positive holes and electrons would be swept out so that no net space charge would be created and the process should, in principle, be possible. Indeed, this has turned out to be so, and although a good deal of sophistication in experimental technique is needed before a drastic reduction in the number of carriers is obtained this has recently been demonstrated by Dr. A. F. Gibson and his colleagues in our laboratory. This is one of the most interesting recent discoveries in this field and may have very important technical consequences. We should note, however, that it is only the intrinsic electrons and holes that may be removed in this way. Those arising from impurity centres may not be extracted because in this case they would not be removed in pairs and a space charge would be set up.

[1] Bardeen, J., and Brattain, W. H., Phys. Rev. **75**, 1208, (1949).

Surface Conditions

Before further discussion of transistor action we must consider some processes that may occur at the surface of a semi-conductor. Under certain conditions, usually due to the presence of impurity atoms on the surface, there exist traps for electrons—known as surface traps. Electrons may fall into these traps and set up a negative charge on the surface. Let us consider then what happens in an n-type impurity-doped semi-conductor. The surface charge comes from electrons stolen from the impurities so that these are left positively charged. Moreover the negative surface charge repels other electrons so that we have a region near the surface with a positive space charge and no carriers other than a small number of intrinsic positive holes which exist in the material. Also a potential hill or barrier is created near the surface over which holes have to climb to leave the surface to pass into the interior of the crystal (see Fig. 5). Now if a positive metal point is placed on the surface its current will try to flow by extracting conduction electrons—but there are none near the surface to extract ! As an alternative it may extract electrons from the full band or what is the same thing it may inject holes. In this case the current is mainly carried by holes, in spite of the fact that in the body of the semi-conductor electrons predominate. Applied positive potential tends to lower the hill so that this process is relatively easy and a low resistance contact results.

If the point contact is made negative the potential hill for holes is made higher and only a very small current will flow—a high resistance contact results (see Fig. 5). We thus have a strong rectifying action, the 'forward' current (electrode +ve) being very much greater than the 'back' current. In silicon the ratio obtainable is very large and this material is now generally preferred for making such rectifying diodes.

Solid Diodes

It was this rectifying property of silicon which first brought this group of substances into great practical importance during the war. A silicon crystal with 'cat's-whisker' contact forms the key part of a microwave receiver although it does not operate as a simple diode, but as a frequency changer. It was such receivers that made wavelengths of 10 cm. and 3 cm. available for operational use in radar during the war. More recent developments have made possible receivers operating down to wavelengths as short as one or two millimetres. The more orthodox diode for d.c. or pulse circuit use is nowadays a very common circuit element and silicon diodes are likely very largely to replace the vacuum tube variety.

The Point-contact Transistor

We already have seen how hole injection from a point contact may influence the current at a neighbouring contact. The great development of transistors has arisen, however, because the variation in the power flowing at the second contact may be made considerably greater than that at the first, i.e. we may have amplification. It is fairly easy to see how power amplification may arise. One contact, called the emitter, biassed positive, will inject holes and will have a low resistance. The other, called the collector, biassed negative, will attract some of the injected holes. It will also have a high resistance. The change in the collector current caused by a change of current in the emitter is of the same order of magnitude and because of the much higher resistance of the collector circuit a large power gain may be obtained. It is this power gain that makes possible the use of the transistor as an amplifier and also as an oscillator.

p-n Junctions

Point-contact transistors have certain limitations arising mainly from the fact that the points have to be fine and placed very close together on the surface. There is, however, another way to use semi-conductors to form rectifying junctions and also to make transistors which does not involve the use of fine point contacts.

Let us consider what happens when an n-type sample of a semi-conductor is brought in contact with a p-type sample. Electrons from the n-type sample flow into the p-type sample and combine with some of the holes (see Fig. 6). This, however, cannot go on indefinitely as a space

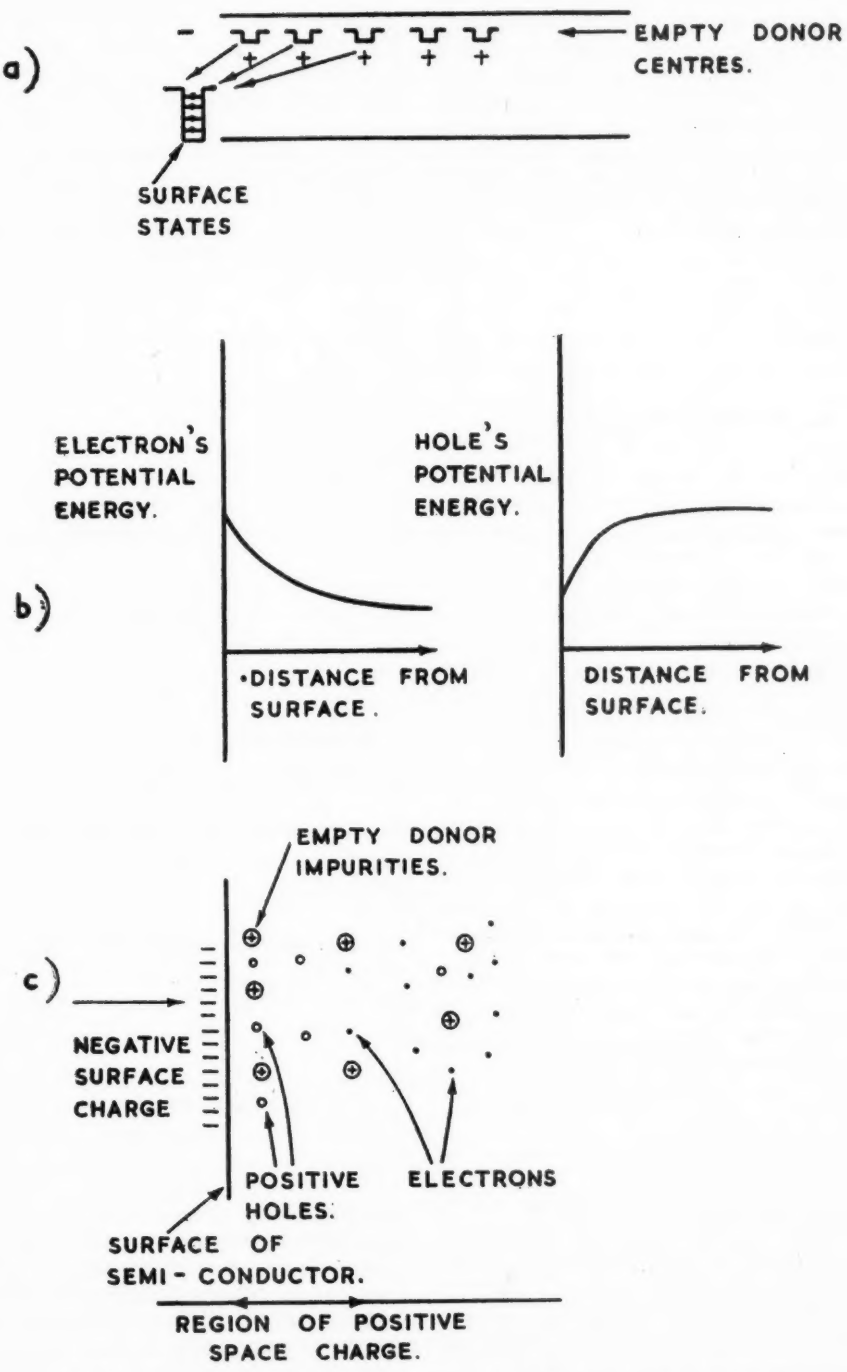


Fig. 5. Formation of potential barrier at surface of n–type semi-conductor.

charge will be left behind and the process is finally arrested by a strong electric field which sets in and creates a hill over which electrons from the n-type sample must climb before they can get into the p-type sample or holes must climb to get from the p-type sample to the n-type. (Note that electron hills look like dips to holes, having an opposite charge.) The effect is illustrated in Fig. 6.

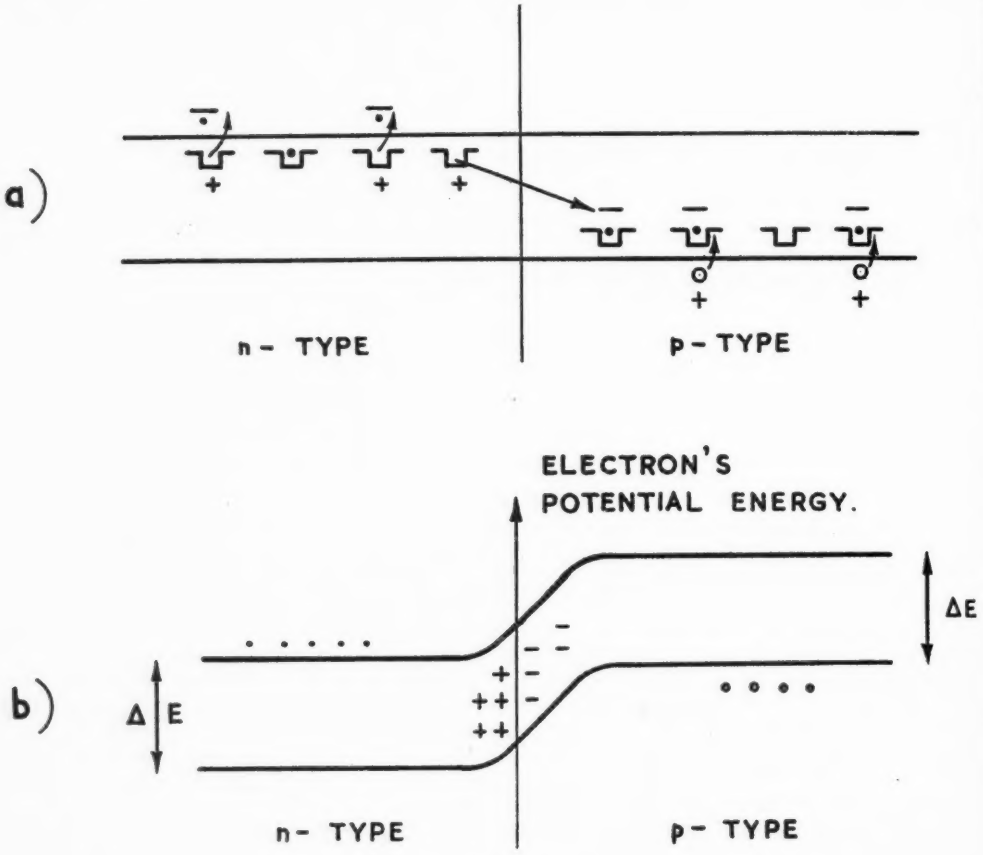


Fig. 6. A p-n junction.

If now, we apply an external voltage across the junction making the n-type end positive and the p-type end negative we effectively increase the height of the hill, but if we reverse the voltage we tend to flatten out the hill. The second arrangement corresponds to easy current flow and the former to hard current flow. We again have a rectifying junction. Particularly with silicon, very high forward to backward ratios may be obtained. Such junction diodes are much more robust than the point contact diodes and may ultimately replace even the present types of low voltage power rectifiers.

Junction Transistors

This effect can also be used for transistor action. In this case a sandwich type construction is commonly used ; a thin wafer of p-type germanium is sandwiched between two n-type crystals—or rather a narrow strip of a single n-type crystal is converted to p-type (see Fig. 7), this leads to a potential hill on either side of the p-type region, giving a kind of potential plateau.

The current through the whole crystal is then controlled by the height of the potential plateau. This in turn can be modu-

lated by means of a voltage between one end of the crystal and the p-type wafer. The plateau therefore acts as a kind of electronic shutter. The voltage control of the p-type region corresponds to the grid control of a triode. This type of transistor is likely to replace the point contact type for many but not for all purposes. It is likely to be much more stable in operation.

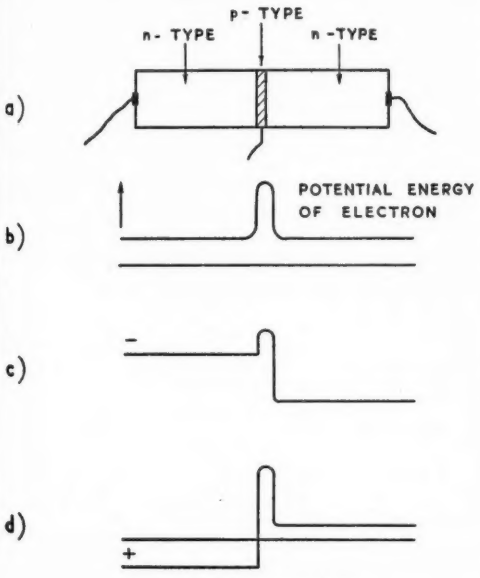


Fig. 7. Junction transistor.

Use of Transistors

The use of transistors in place of vacuum tubes is likely to be general where small space and low power consumption are of prime importance. For example, no H.T. supply is required for a transistor amplifier, a battery giving a few volts only being all that is necessary. A transistor will operate as a low-level amplifier of speech with a power consumption of a few micro-watts whereas a vacuum tube may require of the order of a watt. The use of a vacuum tube in this way has been compared to the use of a freight train to collect a pound of butter ! Transistors are therefore ideal for use as telephone amplifiers in rural areas where no main power supplies are available and in light portable equipment such as deaf aids and personal radio sets. Being just small blocks of crystal with leads attached they are extremely robust and have indefinite life if not over-heated. They are therefore most valuable for use in submarine cable amplifiers which must give long and dependable service without examination or for radio sets for aircraft which under modern flying conditions may be subject to severe shocks. As ' on-off ' devices for use in electronic computors again they are ideal and as soon as industry produces reliable and reproducible forms, which seems likely in the near future, they are likely to replace many millions of valves. Their use for handling relatively high powers and also at very high frequencies is not at the moment so obvious.

Photo-electric Generators

There is one interesting new proposed use of the p-n junction. Such a junction acts as a photo-cell and generates a voltage when light falls on it. This may be readily seen from Fig. 8. If the light creates a hole-electron pair near the p-n junction they will find themselves in a strong electric field which forces the electron towards the n-type and the hole towards the p-type material. The charges are therefore separated and a voltage will build up till this flow is opposed. If now the ends of the p-n sample are joined by a conductor a current will flow. Thus the p-n junction may be used as a generator to turn light into electrical energy. By using a whole bank of such junctions a generator of sufficient power to drive a small radio receiver and transmitter may be made and this has recently been demonstrated using silicon p-n junctions at the Bell Telephone Laboratories in the U.S.A.[1] This may well be one of the important types of application of semiconductors in the future.

New Transistor Materials

So far, germanium has mainly been used as a transistor material, though quite a lot of work has been done on silicon transistors. Experimental transistors using silicon have been made in our laboratory but so far they are not so good as the best germanium transistors and the technological difficulties in handling silicon are very serious indeed. The main drawback in the use of germanium is its failure at temperatures over

[1] Bell Laboratories Record, **32**, 232 (1954).

about 60° C. through the excitation of large numbers of intrinsic carriers. This limits the power-handling capacity of a germanium valve. (This will be readily appreciated by touching the glass envelope of the output valve of a domestic radio receiver after it has been in operation for some time. It will be found to be quite hot !) The phenomenon of carrier extraction may help to alleviate this problem.

Silicon is better in this respect but is difficult technologically. Many laboratories are, therefore, looking for new transistor materials. The most promising line at the moment appears to be with the intermetallic valence compounds, a class of man-made semi-conductors. Typical of these is indium antimonide (InSb). Indium is itself a metal as is antimony. However, indium has 3 valence electrons

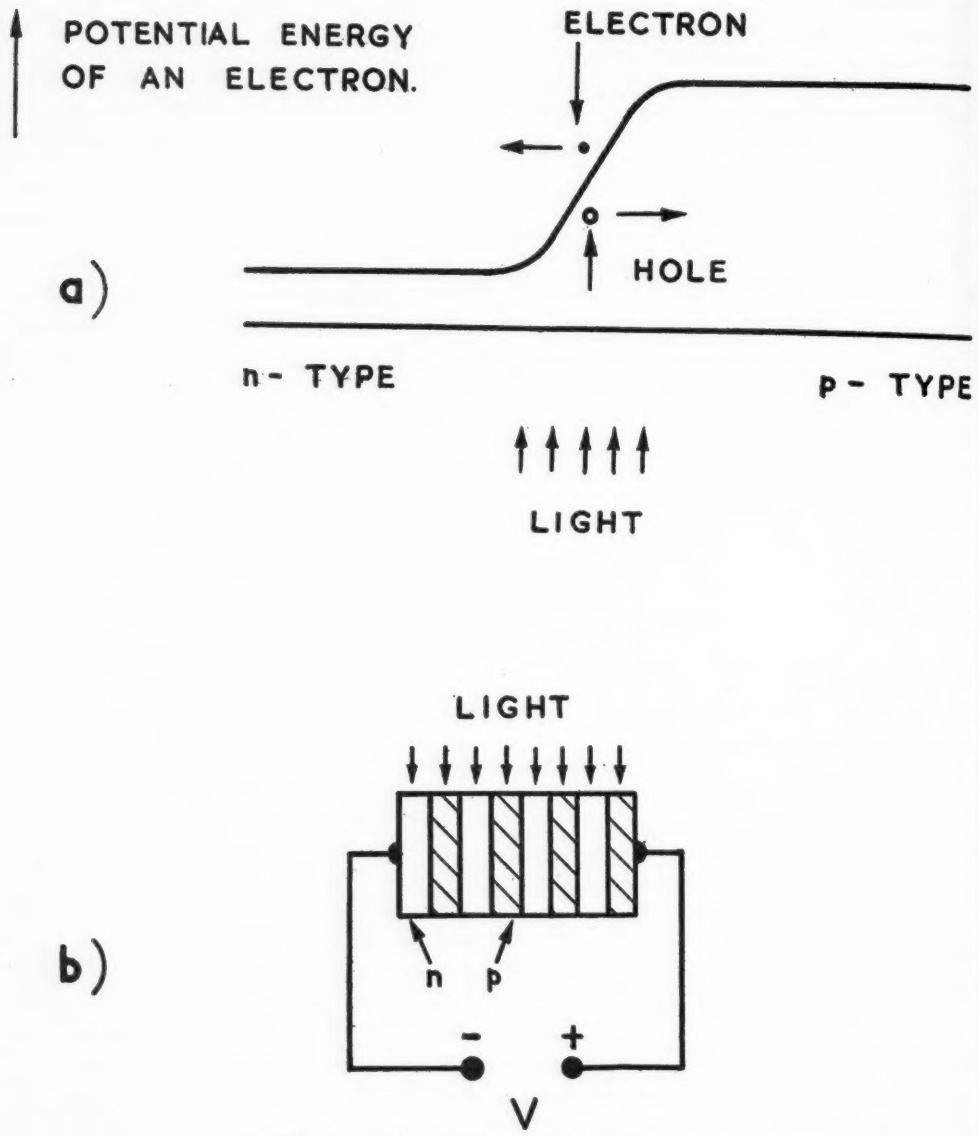


Fig. 8. p–n junction photo-electric generator.

and antimony has 5. If the antimony passes one electron over to the indium they have each 4 and have an electronic structure similar to two germanium atoms. They thus can form a crystal of essentially the same form. The compound is a semiconductor similar in many ways to germanium. This principle is very general and a whole range of new synthetic semiconductors can be made in this way. So far, they have not shown promise of being outstanding transistor materials but it is really too early to say what the future holds. In any case, they form a fascinating new class of substances for study by the solid-state physicist, and are likely to throw a great deal of new light not only on the processes of conduction of electricity but on the binding of atoms together to form solids.

The first half of the present century has been largely devoted to an analysis of matter, that is, to breaking it down into its ultimate constituents, the atoms, and studying these. Their electronic properties are now fairly well known. The two main activities in physics in the second half of the century would appear to be the further study of the atomic nucleus on the one hand and on the other the synthesis of matter, that is, the detailed study of how matter is built out of atoms and indeed the building of new materials not found in nature.

Acknowledgment is made to the Chief Scientist, Ministry of Supply, and the Controller, H.M. Stationery Office, for permission to publish this lecture. The author is much indebted to Miss F. V. Francis for preparing the drawings illustrating in 'cartoon' fashion the processes taking place in semi-conductors.

THE WORK OF THE SCIENCE AND INDUSTRY COMMITTEE[1]

by

PROF. C. F. CARTER

AT the Belfast meeting two years ago the Council, at the instance of the Committee of Section F (Economics), resolved to set up a committee to study ' the problems of speeding up in industry the application of the results of scientific research.' This Committee was constituted by choosing members from the Sections concerned with physics, chemistry, engineering, agriculture and economics—though indeed every Section of the British Association could claim an interest in so large a subject. The Committee was, in effect, sent away to decide what to do—no detailed instructions were given to us. But right at the beginning we had the benefit of the advice of a number of people with great experience of the problems of securing the industrial application of scientific knowledge—including Lord Halsbury, Sir Henry Tizard, and Sir Ben Lockspeiser. We also made, as best we could, a preliminary survey of the contributions which other bodies were making, or had made, within the same field.

If you want to speed up the flow of traffic along a road, you must first of all identify the obstacles which slow it down. There is no point in spending resources in widening the road at A if the real bottleneck comes further along at B. To find out how to speed up the application of the results of scientific research we must first identify correctly the hindrances to that application. As a result of our preliminary enquiries, we came to the conclusion that our knowledge of those hindrances was of a vague and unsatisfactory kind, and that such knowledge as existed was not in the main the outcome of a broad, patient and systematic study of evidence bearing upon the problem in each of its many aspects.

This assertion may sound somewhat presumptuous, in view of the number of eminent individuals and organisations who have over a long period studied the problems of industrial advance. It is very far from my mind to wish to belittle this previous research. But I notice that a great part of it is concerned with particular hindrances—for instance, the shortage of scientists (with whom, throughout this paper, I include technologists), the failure to communicate scientific information, or the failure to communicate it in language which reaches the understanding of laymen. I think that one also needs a general view of all the hindrances, so that one may try to reach some tentative conclusions about their relative importance. For instance, it might be wasteful to increase the flow of scientists to an industry so crippled by financial difficulties that it could afford no expenditure on development ; similarly it is little use pouring money into an industry which lacks the resources in trained personnel to make good use of extra funds.

The Committee's policy is therefore synoptic ; we are interested in the relative importance and the interrelationships of the various factors, as well as in their separate operation. There is a second reason why we could not regard previous research as having yielded a final and scientific assessment of the situation—namely that the situation itself is changing, and requires reassessment. The hindrances to the application of science in 1948, though they might appear to the individual industrialist in the guise of ' red tape,' refusal of permission to raise money, to build a factory, to import a scarce machine and so forth, frequently had their origin in physical shortages—some of them world-wide. In 1954 the

[1] Paper delivered to Section F (Economics) at Oxford on Tuesday, September 7, 1954.

situation is different, and to me much more interesting; the possibilities of development appear far greater, and it becomes necessary to enquire whether they could not be more vigorously exploited.

The research programme which we adopted, therefore, is designed to give us an 'overall view,' and at the same time to keep us close to the industrial realities of the moment. This latter we are trying to achieve by the fashionable expedient of 'case-studies'—studies of the action of particular firms facing particular opportunities of new application of science. Some of these studies culminate in a 'conference' between managerial representatives of the firm and a group of economists and scientists or engineers in an appropriate field of interest, brought together by the Committee. I ought to say here that I have been most impressed by the willingness of firms to help us, even at the cost of much trouble to themselves. We have found everywhere a great interest in our work, and I am sure we could readily occupy five times our staff in following up all the ideas and proposals which have come from our industrial contacts.

The other section of our research programme is back-room stuff, the back room being located in my department at Belfast. It consists of the collection of existing facts which may help to enlighten us about the hindrances to the speedier use of scientific knowledge. Some of these facts are the results of research directed to ends similar to those of the Committee, while other information comes to us as a by-product of other enquiries—for instance, a good deal is embalmed in the evidence to the Royal Commission on the Taxation of Profits and Income. As one might expect, the facts (when they are before us) do not tell us quite what we want to know; and it is then the duty of the Belfast section to conduct additional research to try to fill in gaps and make the information more relevant. An example comes from the theory that British industry is inadequately supplied with persons with scientific and technical knowledge at the level of the Board of Directors or 'top management.' Some work has been done in London on the educational background of directors, and the Manchester Joint Research Council's recent survey yields information about scientists and technologists who have reached senior positions in their sample of firms. There is clearly room for additional work, however, either in cross-checking the qualifications of a sample of directors, or in discovering the technical qualifications of the directors of a sample of companies. Of course, even if such a survey shows a low density of scientists in management, it does not follow that 'more scientists' would inevitably provide 'better use of scientific knowledge'; but there is at least a presumption that firms with scientists at the top would be better able to grasp quickly the significance of new technical developments.

Our plan of work is in each case similar. It starts from a question—to take another example, is the use of scientific knowledge impeded by restrictive practices on the side of the management? We (i.e. the members of the Belfast unit) search the existing literature, and make contact with others who have worked or intend to work on the subject; we then review the gaps in our knowledge, and try to decide whether, within our very limited resources, there is anything we can do to fill them. We do our best to avoid overlapping, though it is difficult to avoid it completely. One apparent overlap is in the analysis of company accounts, on which the National Institute for Economic and Social Research has a major project. We are analysing a sample of accounts of public companies to identify those which are 'financially progressive,' in the sense of having rapidly expanding earnings or assets. These we shall examine further to see whether this quality is in any way related to evidence of technical progressiveness, the employment of scientists, and so on. Tackling the matter from another angle, we are considering whether we can obtain a large number of pairs of firms, each couple making broadly the same products, but subjectively classified (by scientists or engineers) as being one of them 'technically progressive' and the other 'unprogressive.' We shall then look to see which one shows the better financial results. You will see the way in which this enquiry is leading; it is intended to weaken or to strengthen the

suspicion that it does not pay to be quick in seizing new scientific discoveries or methods.

By a happy accident, the broad lines of the research project were settled at about the time when the Board of Trade was able to offer financial help under the Conditional Aid scheme. The grant made to the Committee, though adequate for only about half our original intentions, has enabled us to make a start with the work—in September 1953 at Belfast, and in December 1953 for Professor Williams' section at Keele. Of the two years since our first appointment by the British Association, therefore, we spent one in preliminary planning, the securing of funds, and the recruitment of staff; and those of you with experience of such projects will appreciate that this was not a bad rate of progress. I would like to mention that, perhaps because we were early in the field, we have so far had excellent fortune in the recruitment of staff well-fitted to our needs; and their productivity has been most impressive.

During its second year of existence, the Committee itself has been transformed. The Council of the British Association agreed that the Committee's work was so urgent and important that the Association should seek the co-operation of other bodies in carrying it out. The British Association was fortunate indeed to obtain as joint sponsors of the new project the Royal Society for the Encouragement of Arts, Manufactures and Commerce (the full name of the Royal Society of Arts reminds us of its interest in this field) and the Nuffield Foundation. The Committee was reconstituted in the spring of 1954, with members appointed by all the three sponsors.

I have no intention of giving you an interim report on our conclusions. What we have so far is a collection of half-finished pieces of research work, whose results have not even reached the stage at which they can be reported to the Committee. Naturally some ideas are beginning to bake in the minds of those directly engaged on the work; but so far they are half-baked, and unfit for your consumption. I will express the opinion that the way in which we have tackled the job is a good way, and is showing results. They are not of course neat and tidy results, ready to fit into a final report; that does not happen in industrial research. Some of the most significant results are the ones which are not there (if I may be allowed to be a little Irish): certain possible hindrances to the use of science, which *a priori* look important and are frequently supposed to be so, obstinately refuse to appear in the case-studies. But that may be because our sample so far has been peculiar.

Our plan of work does not stand or fall by the particular research technique with which we have chosen to begin; in the light of experience we shall no doubt change our methods, perhaps making enquiries of narrower scope from a greater number of firms, perhaps planning entirely new pieces of research to fill major gaps which show up when our first general survey is completed. For despite all the work which has been and is being devoted to the subject, I am sure that considerable gaps will remain. Perhaps this Section can help to show us how to fill them.

The trouble is, of course, that the attitude of industry to science is not likely to be the mechanical result of a set of material factors—the kind of factors which can be, in principle at least, measured or described by numbers. Such things as the shortage of scientists or of equity capital, the influence on investment of the size of firms, or the proportions of management with certain qualifications—these may be very troublesome to investigate, but they can be reduced to questions of fact which are precisely defined. But at every point questions of attitude are inextricably mixed with those of fact. Let us look at some examples.

There is undoubtedly a shortage of scientists in the sense that in some branches of science (though by no means in all) good men are sought after, and can early in life command quite high salaries. But suppose that the flow of trained scientists could be greatly increased. I know of no evidence that our methods of selection for university and technical education are so bad that we are letting many first-rate people slip through our fingers. It is probable that an increase in the flow of scientists and technologists would be predominantly composed of people not in the

first rank of ability. How many such people would industry be willing to absorb? Should we soon find that we had crossed that narrow line which separates shortage from abundance? The answer depends on the attitude of different kinds and sizes of firms on the usefulness of employing persons of scientific training; and that is a matter not easily reducible to a calculation in money of the value of a scientist's product. It comes from the general climate of opinion. There are still some hard-headed rugged business men who think a pinch of practice worth a bushel of theory, and who like best the man without formal training who has worked his way up from the bottom. There may be others—I rather think there are—who 'go in' for research because it is fashionable, but who are mildly surprised if their research laboratories produce anything of value to the business. There are others who, perhaps because of the nature of their business, know well that the very survival of their firms depends on their knowledge and speedy exploitation of new discovery. The demand for scientists depends on the way in which such types of attitude are mixed. How, then, can it be assessed?

Another example comes from that favourite theme of company chairmen, the burden of taxation. Certain effects of the taxation system are capable of measurement, though perhaps of a rough and ready kind: for instance, the adequacy of depreciation allowances, or the effects of profits tax on the ways of raising capital. But the most important effects, I think, come from the reactions of high taxation on the way in which individuals approach their work. Theoretical speculation or introspection tells us very little about these reactions. It can be argued that a firm will be less ready to seize the opportunities of scientific advance, because change involves risk, and the profits of success in a risky venture are partly taxed away. It can be argued that a firm will be all the more eager to find out the very best and latest practice, because it has to carry the extra burden of high taxation. It can be argued that it is a firm's relative position in its trade which matters, and that, as long as everyone is taxed on the same principles, taxation is largely irrelevant in determining the urge to progress. It can be argued that finance is not in any case the dominating motive for the adoption of new ideas, and that (provided a firm is left with a fair chance of financing change and development) taxation is again largely irrelevant. It is a fair guess that all these are true in different firms, industries or times, and that the net effect of taxation on the use of scientific knowledge is the resultant of the different ways in which the same tax system causes different people to act. If this is so, how are we to analyse the problem?

A firm which is struggling with financial difficulties may, however open it is to scientific ideas, be unable to face the costs of scrapping existing plant or changing existing methods, and replacing them by new. Unhappily the kind of scientific idea which yields a vast profit for a negligible capital outlay is rare. But a firm which is jogging along very comfortably, giving a fair return to its shareholders and not obviously falling behind its competitors, may well close its mind to the scientist's suggestions for change. Nearly all change involves risk, and why risk a comfortable living for the uncertain chance of a better one? There are a number of points in a firm's growth where change may involve upsetting the managerial structure—for instance, bringing in outside capital and diluting family control. The resistance to the inconvenient incursion of new ideas may be especially great at such points. Again it is a matter of attitude; and the attitude (I suggest) is often determined by the 'planning period' of the firm, by the distance to which it can look, or wishes to look, into the future. For a great many ideas which come from the laboratories of the scientists may still need years of development, testing, sales promotion before they earn their keep. In the long run—to the firm which is prepared to take the long view—they may be just the thing to give a decisive advantage over one's competitors. What determines whether a firm takes a long view? Size, perhaps: and external circumstances—a firm with a precarious hold on fickle export markets can hardly be expected to see much beyond its immediate order book. But to a large extent it must surely be a question of habits of

mind. How can we find out more about them?

You may object that the attitude 'In bad times we can't afford science, and in good times we don't need it' could not stand up long against even a single forceful competitor. It is not at all surprising that there are plenty of firms who have no use for new scientific knowledge; there are no doubt plenty in every country. There is cause for concern only if it is found that they can go on making a comfortable living, year after year, without needing to worry about the competition of more progressive newcomers. To some extent this is made possible because no firm is progressive all ways at once; one may be right up to date in its machinery, but poor at the planning of the flow of work or at marketing, while another will achieve miracles by the skilful use of antiquated processes. But are there industries in which the general climate of opinion about the 'right' ways of doing things, the 'right' products and prices, is so strong that no one ventures to break away? How are such matters to be investigated?

I have asked at a number of points for your views on the ways of investigation of business attitudes. You will see that we are back where we were last year, when this Section sponsored a symposium on 'business decision-making.' Neither the economists nor the psychologists, nor even, I think, the business community itself, know enough about the ways in which people make up their minds—the development of business attitudes, the climate of opinion of an industry. We all generalise on the basis of our own attitudes, forgetting the variety of human response to a single situation. I do not know how much the Science and Industry Committee can add to knowledge on a matter which involves these puzzling problems of attitude. We have at least the benefit of a wide variety of experience in our membership.

HEATING AND VENTILATION

At the Oxford Meeting of the British Association, Section I (Physiology), devoted the morning of September 2 to discussion of the physiological aspects of heating and ventilation. Dr. T. Bedford of the Environmental Hygiene Research Unit introduced the subject and he was followed by Prof. G. P. Crowden, London School of Hygiene and Tropical Medicine, who spoke on *The habitability of dwellings : their heating and ventilation requirements*. Dr. J. R. Brown, also of the London School of Hygiene, then read a paper on *Problems of working conditions in the home*. Dr. A. Parker, C.B.E., Department of Scientific and Industrial Research, spoke on *House heating and atmospheric pollution*. The final contribution came from Mr. J. B. Dick who discussed *Factors of design and construction affecting heating and ventilation in dwellings*.

These papers are printed below in the order in which they were delivered.

Introduction

by

Dr. Thomas Bedford

The object of heating and ventilating a building is to provide a healthy and pleasant environment. Most of the standards of fresh air supply that have been proposed during the last hundred years have been based on the amount of air needed to render body odours imperceptible or barely perceptible. From work carried out in America nearly twenty years ago, it may be concluded that on this basis the supply of fresh air should be at the rate of not less than 600 cubic feet per person per hour. This standard of ventilation was recommended by the Egerton Committee.

With a suitable air supply a comfortable degree of warmth should be maintained. The degree of warmth you need depends, of course, on what you are doing and how you are clad. People wearing normal indoor clothing and doing light work during the winter months in this country like an air temperature of about 65° F., but the majority will be comfortable if the temperature lies between 65° to 68° F. Sedentary persons need temperatures two or three degrees higher.

In warm weather, when people are acclimatised to higher temperatures and also tend to wear lighter clothing, conditions warmer than those acceptable in winter are desirable. Mr. D. E. Hickish tells me that in a recent study of persons doing light work in British factories during the summer months, he found the most-preferred temperature to be 67° F. and the maximum desirable temperature 75° F.

Leonard Hill emphasised the need for adequate air movement, to create pleasant conditions and prevent the feeling of oppression which is so often experienced in a stagnant atmosphere. Observations show that at temperatures of about 65° F. an air speed of much less than 20 feet per minute is liable to result in feelings of stuffiness ; but if the speed exceeds 40 feet per minute complaints of draughts may arise. This narrow tolerance is a trouble that besets the engineer in designing mechanical ventilation. With a given average air speed, the air feels fresher when the speed is variable than when it is uniform.

Nearly a hundred years ago it was said that for comfort the temperature of the walls of a room should be at least as high as the general temperature of the room, and that cold walls made for discomfort. During the course of an investigation in factories some years before the war, Dr. Warner and I became convinced that that view was right, but our conviction was based on chance observations. Since the war some members of my Unit have confirmed this in a study of the subjective impressions of a large group of people. Each person was tested under three sets of conditions, when the temperatures of the

walls, ceiling and floor were maintained uniformly at air temperature, or at some degrees above or below it. In all three conditions the several levels were the same. Over the whole series of experiments, 73 per cent. of the experimental subjects found the warm-wall conditions to be the pleasantest, and of those persons tested in the warmer environments as many as 89 per cent. found the conditions with warm walls pleasanter than those with cool walls.

It is undesirable, however, that one's head should be exposed to undue radiation. Nowadays many buildings are warmed by radiant heat from panels embedded in the ceilings. Recent research has shown that it is undesirable that the elevation of the mean radiant temperature at head level due to the heated ceiling should exceed 4° F. On the basis of this work, tables of the maximum desirable dimensions of heating panels have been prepared and these should be of value as design data.

In some buildings it is convenient to supply heat by warming the floors. A warm floor can be very comforting, but an overwarm floor can be very uncomfortable. It is important, therefore, to know the maximum temperature to which the floor surface should be raised. In the United States floor temperatures as high as 85° F. are used. Some research which my colleagues have almost completed seems to indicate that for sedentary people the temperature of the floor surface should not be higher than 75° F., although people who are moving about may tolerate a rather higher temperature. The experiments have been carried out with the air temperature in the region of 65° F. and the results are therefore applicable to the indoor conditions maintained in British buildings.

Any method of warming which gives distinctly greater warmth near the head than near the floor is undesirable, for if the average temperature is generally satisfactory, the feet will then tend to be cold and the head overheated. Draughts along the floor will aggravate such effects. My colleagues and I have frequently encountered heating installations which have caused the air at head level to be 6° to 8° F. warmer than that near the floor, while at times we have found differences of more than ten degrees. Such conditions were regularly unpleasant, but when the difference between the temperatures at head level and floor level was no more than two or three degrees we were very comfortable. It was reasonable to conclude that the gradient of temperature over the height of a man should not be more than 5° F.

From time to time various scales of warmth have been used to make due allowance for combinations of the individual factors which make up the thermal environment. A scale which has been much used in heating studies in this country is *equivalent temperature*. This is measured directly by means of the eupatheoscope—a blackened cylinder, the surface of which is maintained at a temperature corresponding with that of the surface of the clothed human body. It can be estimated from a knowledge of the mean radiant temperature and the temperature and speed of movement of the air. The scale makes no allowance for humidity, so that it is applicable only for conditions in which men do not sweat.

Of wider application is the American scale of *effective temperature*, which takes into account the temperature, humidity and speed of movement of the air. It makes no specific allowance for radiant heat, however, so that when the mean radiant temperature differs appreciably from the air temperature it may give a misleading impression.

The study of conditions in warships during the Second World War made it necessary to attempt some adjustment of effective temperature for radiation effects, and I suggested that suitable allowance could be made by using the temperature of a black globe thermometer, instead of the dry-bulb temperature, in calculating effective temperature. The figure thus obtained has become known as *corrected effective temperature*. Since the war studies have been carried out at the Tropical Research Unit, Singapore, in which men have been exposed to varying intensities of radiation at high air temperatures. The full results of those experiments are not yet available, but Dr. R. K. Macpherson tells me that comparisons of the physiological reactions with corrected effective

temperature show that the globe thermometer adjustment gives excellent results.

Physiological studies carried out during the war led to certain criticisms of effective temperature as an index of the stress imposed by work in hot environments. Of the various bodily responses to heat, the rate at which a man sweats seems to be a good index of stress, and my colleague, Mr. Frank Smith, has tested the accuracy with which the rate of sweating can be predicted from a knowledge of the effective temperature, using the results of experiments carried out at the National Hospital, Queen Square.

Mr. Smith has shown that the criticisms of effective temperature are valid, but they refer only to very hot conditions such as industrial workers are not generally expected to endure. Effective temperature does not give quite as good a prediction of the rate of sweating as does a scale specially constructed for that purpose—the predicted four-hour sweat-rate—but the difference in accuracy is not great and errors are considerable with either method. The conclusion is that, in spite of the criticisms that have been levelled against it, effective temperature, properly used, remains a valuable index of warmth.

Investigations of heating and ventilation, whether relating to comfort or to engineering methods, have commonly been concerned with the requirements for factories or other large buildings. Since the war, however, increased attention has been paid to the needs for houses. In this connection Professor Crowden and his colleagues have carried out various physiological studies, and at the Building Research Station Mr. Dick and his co-workers have made important investigations of heating and ventilating methods.

Yet there is perhaps a gap in our research. It may seem rather costly to warm a large room for the benefit of a single occupant, or to warm a room to temperature that is uncomfortable for the other members of the family in order that an aged grandparent may be kept warm. In recent years Colonel Newcombe has repeatedly urged that local methods of warming the person, rather than the whole room, should be studied. And in America the eminent physiologist, Dr. E. F. Du Bois, advocating the study of local heating, suggested that where there is no open fire one might provide an electrically heated armchair. He asked—'Why overheat 100 tons of house and furniture, when all that is necessary is to warm 100 lbs. of grandmother?'

The Habitability of Dwellings: Heating and Ventilation Requirements

by

Prof. G. P. Crowden, O.B.E.,

Introduction

This communication is concerned with the heating and ventilation of dwellings of modern type in the British Isles; the physiological considerations justifying present-day standards for indoor warmth and fresh air supply; and some of the findings of recent research on habitability problems of housing in which physiologists, physicists and heating and ventilating engineers have collaborated.

The fitness of a dwelling for human habitation depends on the extent to which it is capable of satisfying requirements for health, comfort and well-being.

In the determination and specification of good standards for housing many branches of science have helped to solve problems of design, construction, services and provisions for heating, ventilation and lighting.

As long ago as the spring of 1942, in spite of, but due to, the stress of war-time conditions, the authorities responsible for health and housing commenced planning to meet an estimated need for three or four million new houses when the war ended. Among the many requirements listed in a series of valuable official publications entitled 'Post-War Building Studies,' it was laid down that adequate facilities for heating and ventilation must be provided in dwellings. These requirements are of particular physiological interest because air temperature, humidity, radiant heat, air movement and fresh air supply affect such vitally essential processes as those concerned with body temperature control and respiration. In health, if the indoor climatic conditions satisfy physiological needs we are quite unaware that the physiological processes involved in body

temperature regulation and respiration are taking place continuously and efficiently, but if not, then sensations of thermal discomfort, unpleasant smells, excessive fatigue and sometimes respiratory distress may be experienced. Such sensations are indeed warnings that action is called for to adjust and control room climate by the appropriate use of fires, windows, doors and cooking and washing appliances.

The amount of heat produced by an adult, even when sitting at rest is considerable, namely some 400 B.Th.U.'s or 100 kilogram calories per hour. This amount of heat would raise the body temperature 3° F. if it could not be given off to the external environment by radiation to cooler surroundings, convection to the air, and the evaporation of moisture from the lungs and skin. In an unventilated room at 60° F. the amount of heat given off by convection could raise the temperature of 600 cubic feet of air 10° F. in one hour.

Heating and Ventilation Standards

The standards for indoor warmth and ventilation given in the Codes of Practice drawn up by the British Standards Institution may be summarised as follows :—

	Air Temperature	*Humidity*	*Fresh Air Supply*
Living Rooms	60° F.–68° F.	30–65 per cent.	600 cubic feet per hour per person
Bedrooms	55° F.–57° F.	30–65 „ „	600 „ „ „
Kitchens	60° F.	Less than 70 per cent.	2,000 cubic feet per hour.

It is also recommended that the temperature of the air in living rooms should not be more than 5° F. higher at head level than at foot level, and also that the air movement should range from 20–40 feet per minute at these temperatures, although velocities up to 100 feet per minute may be desirable in hot summer weather. If there is a high temperature source of radiant heat in the room the comfort zone for air temperature is 58° F.–62° F.

Findings of Recent Research

Research, the facilities for which were provided by the Ministry of Works and the Building Research Station of the Department of Scientific and Industrial Research, has been carried out on a number of problems in specially constructed experimental rooms (Fig. 1) of the type described as kitchen living rooms in houses designed for a family of four. Housewives and men of varying age acted as subjects.

It was shown :—

(i) That the provisions for heating and ventilation enabled desirable conditions to be readily maintained when the rooms were fully occupied.

(ii) That conditions falling within the range recommended in the Codes of Practice could be as readily maintained in rooms 7 ft. 6 ins. in height as in those 8 ft. in height. A field survey of houses having rooms of this height showed that families were living in comfort in them. Very few expressed an opinion that they would like higher rooms, and the majority had not noticed they were 6 ins. lower than usual. These findings have already been of considerable importance owing to the urgent need for providing as many good houses as possible with the resources available.

(iii) That, when using ordinary gas wash boilers and cookers in small kitchens, the ventilation needs to be very much greater than the 2,000 cubic ft. of fresh air per hour laid down for general use, if undesirable conditions of heat, humidity and air purity are to be avoided. This problem can only be satisfactorily solved if the heat, humidity and products of gas combustion are led directly into the open air. Experiments have shown that it is possible to do this without impairing either washing or cooking operations carried out by the housewife.

(iv) That the air change in the rooms can be reduced to less than one per hour if the windows are closed and the chimney flue sealed. While this renders heating by open coal fires impossible, and the use of gas heaters dangerous, it may be very necessary to take such action when the outside air is grossly polluted as in times of 'smog.' The indoor air under such

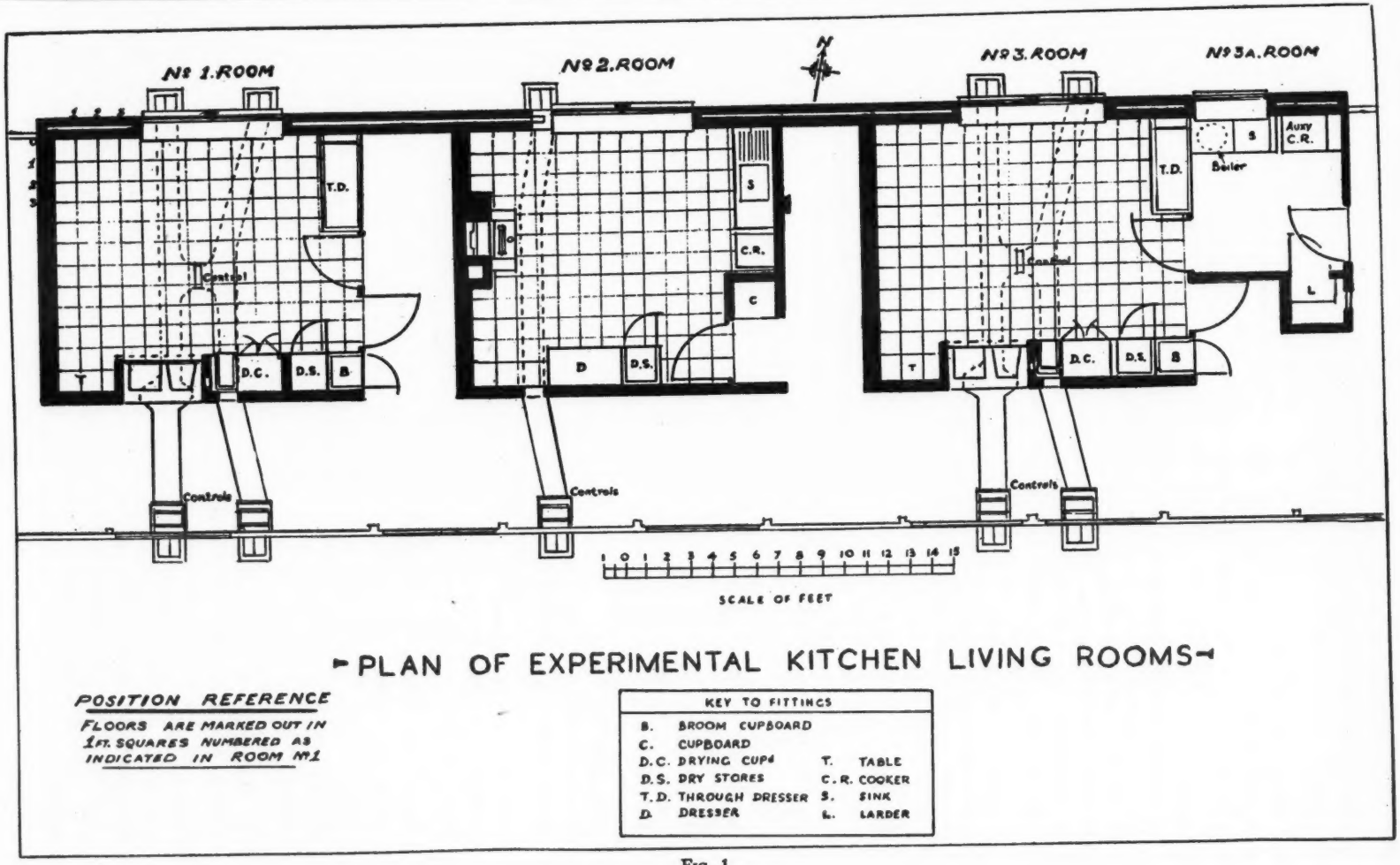

Nº 1.ROOM
Nº 2.ROOM
Nº 3.ROOM
Nº 3A.ROOM
N
T.D.
Control
D.C.
D.S.
B
T
S
C.R.
C
D
Auxy C.R.
Boiler
L
Controls
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SCALE OF FEET
PLAN OF EXPERIMENTAL KITCHEN LIVING ROOMS
POSITION REFERENCE
FLOORS ARE MARKED OUT IN 1FT. SQUARES NUMBERED AS INDICATED IN ROOM Nº1
KEY TO FITTINGS
B. BROOM CUPBOARD
C. CUPBOARD
D.C. DRYING CUPS
D.S. DRY STORES
T.D. THROUGH DRESSER
D. DRESSER
T. TABLE
C.R. COOKER
S. SINK
L. LARDER

FIG. 1.

conditions will be more respirable than that out of doors owing to the absorption of harmful constituents by the walls and furnishings of the room. Owing to the reduction in air change less heating will be required for warmth and when electricity is available this can readily be achieved.

An average adult sitting at rest requires to breathe approximately 15 cubic ft. of fresh air per hour in order to meet his continuous need for oxygen. Hence, even if the ventilation of a room of 1,200 cubic ft. capacity was reduced to one half of an air change per hour, viz. to an entry of 600 cubic ft. of outdoor air per hour through the cracks round windows, etc., this would amply satisfy the physiological requirements of the occupants for oxygen.

Conclusion

Finally, it must be emphasised that while the facilities for attaining desirable indoor conditions of warmth and fresh air ventilation are provided in modern houses, it rests with the occupants themselves to make proper use of them.

Two recent examples of failure of the occupants to do so are worth quoting because they show what serious results may follow disregard of physiological requirements.

The first is a case of a well-built and well-furnished house which became uninhabiable. The occupants complained that they felt such acute discomfort in it that they had to sleep elsewhere and only used the house for short periods during the day time. They claimed that their ill health was due to the house. Thorough inspection of drains, chimneys, services and construction by the authorities did not reveal any defects. My colleagues and I visited the house. On entry it smelt fusty, felt cold and the indoor climate was dank and stagnant. Measurements of air temperature in the living room showed it to be 3–5 degrees below the minimum level for comfort. The fresh air supply was about half the minimum requirement, and the air was so still that our instruments could not detect any movement. The occupants said they could not get fires to burn and that the gas appliances made the air unpleasant.

The cause of this state of affairs was traced to the fact that the occupants systematically avoided opening windows and had made excessive use of draught-excluding devices which they had had fitted to all external doors and round the windows. They had also blocked up all air-brick ventilators with paper. The need for ventilation was explained but they would not act on the advice. They subsequently left the house, but the new occupants who took it over acted on the recommendations, and have had no complaints to make about it.

The second case is indeed tragic for it involved the deaths of a grandmother and three young children and the serious illness of the mother and another child. During a spell of cold weather this family slept in the living room as it was warmer than the bedrooms. They had closed the window and packed it with paper and felt to exclude draughts. They had closed the damper plate in the chimney. On going to bed they turned down the gas fire but left it and a gas light burning. The cause of death was carbon monoxide poisoning, due to the incomplete combustion of gas as the carbon monoxide concentration in the room air rose and the oxygen percentage fell.

These two recent cases illustrate the urgent need for a better understanding by the general public of the significance to comfort and to health of such everyday matters as heating and ventilation in the home.

References

Bedford, T. (1946) : ' Environmental Warmth and its Measurement.' *M.R.C. War Memorandum No. 17.* H.M.S.O.

Crowden, G. P. (1951) : ' The Height of Rooms in Dwellings in Relation to Health and Comfort.' *J. Roy. Sanit. Inst.*, **72,** No. 2.

Crowden, G. P. (1952) : ' The Ideal Home : Optimum Living Conditions in Temperate Climates.' Symposium on Climate, Environment, and Health. *Practitioner*, **168,** 593–604.

Post-war Building Studies, published for the Ministry of Works :

No. 19. ' Heating and Ventilation of Dwellings.' By the Heating and Ventilation Committee of the Building Research Board of the Department of Scientific and Industrial Research. H.M.S.O., 1945.

Codes of Practice, British Standards Institution :

CP3—Chapter I (C) : ' Ventilation,' 1950.

CP3—Chapter VIII : ' Heating and Thermal Insulation,' 1949.

Physiological Reactions of Women to Heat and Humidity During Work in the Home

by

Dr. J. R. Brown

By the housewife the weekly wash is often regarded as a necessary burden. In this age of washing machines and 'washing parlours' the weekly wash has become less formidable. Nevertheless, there are countless women who do not possess a washing machine and who still use the old well-tried methods. The methods employed in general consist of washing, scrubbing, boiling and wringing.

Experimental studies have been carried out to investigate the effect of heat and humidity in rooms where the 'weekly wash' was done. For this purpose a full scale user-test investigation was made at the experimental kitchen living rooms at the Field Test Unit of the Building Research Station.

The room in which the investigation took place was a kitchen living room of the modern convertible flat type, 14 ft. × 12 ft. × 8 ft. The room had two casement type windows opening on to the exterior with two hopper type windows opening above them.

Since we wanted to know the effect of heat and humidity on the housewife we imposed two sets of conditions upon her. Firstly, we allowed her to have as many doors and windows open as she desired, i.e. *maximal ventilation*, and secondly, we controlled the ventilation by allowing the right-hand hopper only to be open, i.e. *the ventilation was restricted.* The amount of washing done was that of an average family of four persons and occupied the whole day. Before lunch the clothes were washed and scrubbed and then boiled in a gas wash boiler; after lunch the clothes were rinsed, wrung, and hung out. Four subjects were studied, one working and one as a resting control on each occasion. Thus each subject took part in four experiments. Throughout the day measurements were made of the temperature and humidity of the working space and of the physiological reactions of both subjects. A pilot study had shown that the following physiological observations could be made without hindering the performance of the subjects:

(i) Pulse rate and blood pressure changes for the Crampton Index.
(ii) Sensations of heat, moisture and freshness.
(iii) The electrical conductivity of the forehead skin as an index of sweating.

The Crampton Index

This index of the efficiency of the vasomotor control is based on alterations in pulse rate and blood pressure on actively changing from a recumbent to an erect posture. In 1923 the New York State Ventilation Commission reported that 'A high room temperature such as 86° F. with a relative humidity of 80 per cent. produces a slight but distinct animation of the body temperature, an increase in the resting pulse rate and a lowering of the subject's blood pressure resulting in a marked fall of the Crampton Index.'

It should be stated that the average range of the Crampton Index for normal subjects is 50–100. The Crampton Index has in the past been subject to a good deal of criticism especially with regard to its reliability. However, we have found that it is not individual values that are important, but the changes in the index which occur when the environmental conditions are altered. That is, trends in the Index are more important than individual values.

Summated Sensations

A scale of sensations related to heat and moisture was described by Crowden and Lee (1940). (*See* Appendix.) It is important that the subject clearly understands what each sensation represents. When this is done and the subject fully grasps what is required the scale can be used with great advantage. As with the Crampton Index it is trends in the changes in sensation that are important.

The Electrical Conductivity of the Skin

This was measured by a small electric current through the skin. The actual current passing was measured on a very sensitive ammeter. Any change in current

may be considered as due to change in sweat gland activity. (Number of active sweat glands.) Experiments have been carried out which demonstrate the validity of this relationship. The relation of the electrical conductivity of the skin to the number of active sweat glands has been studied. The plastic impression of Thomson and Sutarman was used for the enumeration of the sweat glands. It was found that there was a significant correlation between the numbers of active sweat glands and the skin conductivity ($r = +0{\cdot}61$ for 112 observations on four subjects).

To return to the subjects engaged in clothes washing. During each experimental session the environmental conditions and the thermal sensations of the subjects were recorded as well as their physiological reactions. Two distinct sets of environmental conditions were studied :

1. Maximal Ventilation
2. Restricted Ventilation

The results obtained from a typical pair of experiments indicated that :

(i) The Crampton Index is low when the wet bulb temperature (W.B.T.) is high.
(ii) The value for the summated thermal sensations is maximal at the peak values of the W.B.T.
(iii) The difference between the W.B.T. on the two days, although not large is related to (i) and (ii) above.
(iv) Activity caused a fall in the Crampton Index, this fall being greater on the day when the W.B.T. was higher.

That these changes are related to environmental heat and humidity is shown by the following observations :—

(*a*) The amount of work done on each day was the same.
(*b*) The initial values of the Crampton Index were the same.
(*c*) The general trends of the Index were the same.

It is interesting to note that the subjects complained of fatigue at the time when the Crampton Index was low when compared with its initial resting value. A similar type of result was obtained from all four subjects. The experiments have shown that there was also a difference in the Crampton Index between the two days for the resting subjects. But this was only significant when the difference between the wet bulb temperatures were significant.

The experiments have also shown that when the summated sensations of heat and moisture reach their maximal values the electrical conductivity of the skin is also at a maximum.

An analysis of the results has shown that small increases in the wet bulb temperature in the range 65°–75° F. caused marked increases in sweating on the day when the ventilation was restricted (air movement 10 ft./min.). It is interesting to note that in a series of more recent experiments in which tropical clothing was worn marked increases in sweating did not occur until a W.B.T. of approximately 75° F. was reached when the air movement was 100 ft./min.

The results of these experiments may be summarised thus: Although the Crampton Index follows the same general trends on both days the fall was significantly lower on the day when the wet bulb temperature was higher due to restricted ventilation. That is, when the thermal stress imposed upon the subject was greatest as indicated by the maximal W.B.T., it evoked maximal thermal sensations. That the thermal stress was greater when the ventilation was restricted is also indicated by the fact that sweat gland activity as given by the electrical conductivity of the skin was also greater.

Three of the subjects took their midday meal in a room adjoining the working space, the fourth in the working space. It is interesting to note that during this time in the case of the three subjects the value of the Crampton Index tended to approach the initial pre-experimental resting value, whereas for the fourth person this increase was much less.

Thus it can be seen that if the wet bulb temperature of the air of the room where washing is being carried out rises markedly due to restricted ventilation (2–3·5 changes/hr.) greater physiological stress is thrown upon the housewife than when the ventilation is the maximum obtainable by opening doors and windows.

Having observed the relationships between changes in Crampton Index, summated thermal sensations, and skin conductivity in the user-test experiments it was felt necessary to establish their validity under controlled conditions in the laboratory. For this purpose a planned series of experiments was carried out in an air-conditioned cubicle at the London School of Hygiene and Tropical Medicine. In this cubicle the temperature and humidity of the air could be altered at will. In these experiments six medical students were used as subjects. It was shown that increases in environmental heat cause a fall in the Crampton Index. The rate of fall increased when a standard amount of exercise (step climbing) was carried out. It was found that there was a linear correlation between decreases in the Crampton Index and increases in the wet bulb temperature and in the Corrected Effective Temperature which also comprises the radiation factor.

The results obtained from one such series of experiments in which the changes were plotted against the corrected effective temperature over a range 55°–90° F., showed that there is a linear fall in the Crampton Index and a linear rise in the summated thermal sensations with increase in C.E.T. There is also a sudden rise in the electrical conductivity of the skin, and at this point it was generally noticed that droplets of sweat became visible on the skin surface.

The experiments were carried out in humidities of 60 and 80 per cent. Refering once more to the summated thermal sensations it was found from these experiments that thermal discomfort occurred when the subjects were exercising at a C.E.T. of 78·54° F. and when resting at 82·0° F.

Recently a field survey was carried out on women washing in the kitchen living rooms of their own homes. As expected it was found that the majority of housewives found it necessary to increase ventilation in order to control temperature and humidity in the rooms.

Housewives often spread their 'wash day' over two days, washing and scrubbing one day, boiling on the other. When this is done it was found that maximal fall in the Crampton Index was 12–25 per cent. whereas when it was done all in one day the fall was 45–55 per cent. of the initial resting value. This group of subjects complained of feeling tired whereas the former group did not. From all these observations it can be seen that the ventilation and wet bulb temperature of a room where washing is being carried out are of the utmost importance, since in the higher temperature ranges small increases in the W.B.T. may aggravate physiological reactions.

Acknowledgments

Dr. P. F. Taylor collaborated with me in the studies referred to which formed part of a programme of research on housing carried out under the direction of Professor G. P. Crowden on behalf of the Building Research Station of the Department of Scientific and Industrial Research.

References

Crampton, G. W. (1913). 'Blood Ptosis, a test of vasomotor efficiency.' *N.Y. med. J.* Nov. 8.

Crampton, G. W. (1915). 'The Blood Ptosis Test and its use in Experimental Work in Hygiene.' *Proc. Soc. exp. Biol.* **12,** 119.

Crampton, G. W. (1920). 'The Gravity Resisting Ability of the Circulation : its measurement and significance (Blood Ptosis).' *Am. J. med. Sci.* **160,** 721.

Crowden, G. P. & Lee, W. Y. (1940). 'Sensations of heat and moisture.' *Chin. J. Physiol.* **15,** 475.

Taylor, P. F. (1952). 'Thermal Comfort Sensations and Physiological Reactions in relation to Variations in Indoor Climate.' Thesis, Ph.D. University of London.

Thomson, M. L. & Sutarman (1953). 'The Identification and Enumeration of Active Sweat Glands in Man from Plastic Impressions of the Skin.' *Trans. roy. trop. Med. Hyg.* **47,** 412–417.

Ventilation Report of the New York State Commission on Ventilation. E. P. Dutton, 1923.

APPENDIX

Thermal Comfort Sensation Scales

Heat Scale

(a)

Sensation	*Code No.*
Unbearably hot	+ 7
Much too hot	+ 6
Too hot	+ 5
Hot	+ 4
Too warm	+ 3
Warm	+ 2
Comfortably warm	+ 1

Sensation	*Code No.*
Neutral	0
Comfortably cool	− 1
Cool	− 2
Too cool	− 3
Cold	− 4
Too cold	− 5
Much too cold	− 6
Unbearably cold	− 7

Moisture Scale

(b)

Sensation	*Code No.*
Unbearably moist	+ 7
Much too moist	+ 6
Too moist	+ 5
Moist	+ 4
Too humid	+ 3
Humid	+ 2
Comfortably humid	+ 1
Neutral	0
Comfortably dry	− 1
Dry	− 2
Too dry	− 3
Parched	− 4
Too parched	− 5
Much too parched	− 6
Unbearably parched	− 7

Freshness Scale

(c)

Sensation	*Code No.*
Very stuffy	+ 2
Stuffy	+ 1
Comfortable	0
Fresh	− 1
Very fresh	− 2

Instructions

Look at the above scales (a), (b) and (c) and decide which Code number in each scale corresponds to the sensation you feel at the time. Then note down the Code number and time of observation in the correct position on your record sheet.

E.g. If you feel (a) Warm (+ 2), (b) Comfortably dry (− 1) and (c) Stuffy (+ 1) at 12 noon you would fill in the record as follows :—

Time	12 noon
Heat	+ 2
Moisture	− 1
Freshness	+ 1

House Heating and Atmospheric Pollution

by

Dr. A. Parker, C.B.E.

Introduction

Gross contamination of the air of our large towns is part of the price that has so far had to be paid for the development of industry in Great Britain during the last 200 years to enable this country to support a rapidly increasing population at a rising standard of living. This development has been based on the use of coal as the major source of heat and power ; and it is mainly from the use—or rather misuse—of this indigenous fuel and its products that the air of our towns is now so heavily polluted.

Nature and Amount of Pollution from Domestic Grates

Of the various products of combustion and partial combustion of coals and oils and their products, those causing serious pollution of the atmosphere are given in Table I.

In 1952, the total inland consumption of coal was about 205 million tons. This amount was divided among the main broad uses as shown by the figures in the second column of Table II. Of the total of 205 million tons, 53 million tons, or one-quarter, was carbonised in coke ovens, gas works and low-temperature carbonisation plants to provide coke or smokeless solid fuel, gas, tar, motor spirit and other by-products. The remainder, about 150 million tons, was burned as raw coal, much of it inefficiently, with the production of large quantities of smoke and other pollutants. It included 37 million tons used with low efficiency in household grates.

In Table II, estimates are included to the nearest 0·1 million tons of the amounts of each of the main pollutants discharged into the air from the various uses of coal, coke, and gas. The weight of the tarry and other carbonaceous matter in the smoke produced was about 2 million tons a year. Nearly one-half of this smoke was from domestic grates, though they used less than one-fifth of the coal consumed ; this is because the domestic grate produces much more smoke per ton of coal burned than is produced on average by industrial

TABLE I

Pollution Substances from the Combustion of Coal and Oil and their Products

1. Solid	Particles of carbon or soot causing black smoke, and particles of coal, coke and ash carried forward as grit in the chimney gases.
2. Liquid or semi-solid carbonaceous matter	Particles of tarry matter causing yellowish brown smoke.
3. Unburned and partially burned gases	Hydrocarbons and carbon monoxide.
4. Sulphur oxides	Sulphur dioxide gas and sulphur trioxide mist, which with water give sulphurous and sulphuric acids.

furnaces. Nearly one-fifth of the sulphur arose from domestic appliances burning raw coal.

Effect of Recent Changes in Domestic Fuel Consumption on Air Pollution

In addition to raw coal, large quantities of coke, gas, and electricity are used for domestic heating and cooking. As a result of the rationing of household coal, these quantities are now much greater than they were before 1939, while the quantity of raw coal consumed in domestic grates is much less. This point is well brought out by the figures in Table III for the domestic consumption of coal, coke, gas, and electricity in 1938 and in 1952.

TABLE II

Main Uses of Coal and Estimates of Pollution from such Uses in Great Britain in 1952

Type and use of fuel	*Quantity of coal (millions of tons per annum)*	*Pollutants discharged (millions of tons per annum)*		
		Smoke	*Grit*	*Sulphur dioxide*
Coal burned :				
Domestic use	36·9	0·9	0·1	0·9
Electricity works	35·7	small	0·2	1·0
Railways	13·9	0·3	0·1	0·4
Other industrial uses, including collieries	65·1	0·8	0·2	1·8
Coal carbonised :				
Coke ovens and use of coke	25·2	small	small	0·5
Gas works :	27·9	small	small	0·1
Use of gas	—	nil	nil	small
Use of coke	—	nil	small	0·3
Totals	204·7	2·0	0·6	5·0

TABLE III

Domestic Consumption of Coal, Coke, Gas, and Electricity in 1938 and 1952

Year		*Millions of tons*
1938	Coals and anthracite	50·4
	Coal in making 2·5 million tons of coke and 925 million therms of gas	7·4
	Coal in providing 5,360 million units of electricity	4·1
	Total domestic coal consumption	61·9
1952	Coals and anthracite	36·9
	Coal in making 3·5 million tons of coke and 1,363 million therms of gas	10·6
	Coal in providing 16,197 million units of electricity	11·2
	Total domestic coal consumption	58·7

This change in the pattern of domestic fuel consumption has reduced the quantities of the main pollutants discharged from the domestic chimney. In 1938, the quantity of smoke from domestic chimneys must have been nearly 1·3 million tons and the quantity of sulphur dioxide (including that from the coke burned) was about 1·3 million tons, whereas the corresponding quantities for 1952 were 0·9 million tons of smoke and 0·9 million tons of sulphur dioxide. Though little or no smoke was produced at the gas and electricity works in providing the additional gas, coke, and electricity for domestic heating in 1952, there was an additional quantity of 0·2 to 0·3 million tons of sulphur dioxide emitted from the chimneys of electricity works.

In comparing the effects of the pollutants discharged from domestic chimneys with those of the pollutants from industrial chimneys, several factors in addition to total quantities of pollutants must be considered. Domestic chimneys are not nearly so high as most industrial chimneys with the result that the same amount of pollutant from domestic chimneys may have a greater effect in contaminating the air near ground level. A larger proportion of the pollution from domestic chimneys occurs during the colder months of the year when there is the greatest chance of fog with little or no wind to disperse it. It was estimated that during the London 'smog' of December, 1952, 60 per cent. of the pollution of the air in that area came from domestic chimneys.

METHODS OF REDUCING AIR POLLUTION FROM DOMESTIC GRATES

Smoke

The problem is to eliminate or at least greatly reduce the pollution from domestic chimneys while maintaining or improving the conditions of heating and ventilation in our houses. Possible ways of reducing the pollution by smoke are (1) to develop the use of more efficient coal-burning grates and stoves, whereby less coal is burned for the same amount of useful heat, (2) to introduce grates and stoves that will burn bituminous coal without producing smoke, (3) to extend systems of central heating for groups of dwellings, so that coal can be burned smokelessly in large central installations, (4) to replace household coal by smokeless fuels such as coke, anthracite, oil, gas, and electricity.

In considering the first of these possibilities, it is necessary to have a clear idea of what is meant by efficiency. It is not enough to measure by physical methods the amount of heat transmitted into the room or house in relation to the thermal value of the fuel consumed, as there are also physiological, psychological, and traditional factors. The simple open fire in common use in this country for burning bituminous coal ordinarily radiates into the room about 25 per cent. of the thermal value of the coal burned. In addition, heat is transmitted by conduction and convection from the fireplace surround and chimney breast. But the fire also acts as a fan and often draws through the room as much as 8,000 cubic feet of cold air from outside every hour, whereas 2,500 cubic feet would be adequate for satisfactory ventilation of the living room of an average dwelling when occupied by four people. In very cold weather this cooling effect of excessive ventilation can be considerable and certainly unpleasant. By proper design of the throat of the chimney above the fire, or by installing a suitable throat restrictor, the amount of air drawn through the room can be reduced to 3,500 or 4,000 cubic feet per hour without causing down-draught. In this way the effective efficiency of the open fire as indicated by personal comfort can be raised by several per cent.

Modern openable and closed stoves are much more efficient than the simple open fire in their use of coal (or other solid fuel) for heating a room, often twice as efficient. They emit less radiant heat, but much more heat by convection ; and they do not draw excessive quantities of cold air from outside into the room. Experience has shown that in our climate the occupants of a room demand for personal comfort an air temperature of 5° to 8° Fahrenheit higher, when the heating is mainly by convection than when it is mainly by radiation. It has also been found that even with appliances of the same type but of different thermal efficiencies, most of the extra efficiency is used to provide a warmer room or house, with the result that there is no great saving of fuel. The average Britisher definitely prefers an open fire or an openable stove to a closed stove in our climate.

The general conclusion is that the use of coal-burning appliances of greater efficiency, though providing some measure of greater comfort, is unlikely greatly to reduce coal consumption and smoke emission.

For heating an individual room there have been many attempts to develop appliances that will burn bituminous coal with the emission of little or no smoke. Some measure of success has been achieved with the larger closed stoves operated continuously, but the prospects of developing an open fire or openable stove suitable for operation by the average householder to burn coal relatively smokelessly at the varying and often low rates needed in our changing climate do not seem to be great.

With central and district heating for large blocks of flats, and groups of houses, coal can be burned in the large central boilers with little emission of smoke. Experience has shown, however, that the amount of fuel consumed per household is greater than with individual house heating. This is largely because the cost is included as a uniform amount in the rent, so that the householder receives no commensurate financial benefit from personal efforts towards fuel economy. Such schemes are in consequence more costly and will continue to be so until there is a satisfactory method of measuring the heat service taken by each householder and charging accordingly.

There remains the possibility of replacing the bituminous coal used in individual houses by solid smokeless fuels and by oil, gas, and electricity. As we do not possess any appreciable indigenous resources of oil, it is not economically desirable, nor would it be acceptable, to replace a substantial amount of the 37 million tons of household coal now used by oil.

It is not economic to store an amount of gas much greater than the maximum demand over 24 hours ; and there is no economic method of storing large quantities of electricity. If the major part of the household coal now used in the winter were replaced by gas and electricity, it would be necessary greatly to extend gas and electricity works to meet heavy loads over short periods, at a cost that would be unduly high. The prospects of greatly increasing the quantities of anthracite and

other relatively smokeless coals for use in the domestic grate do not seem promising. It thus seems that the most practicable and least costly method of reducing pollution by smoke from domestic chimneys is to replace the bituminous coal mainly by coke from the carbonisation of coal at high or at low temperature, and partly by gas and electricity. This means increasing the supplies of domestic coke of suitable grade of size and quality (low ash content and easily ignited) partly by diverting some of the coke now used in industry but mainly by increasing the production of suitable coke. During the carbonisation of coal for the manufacture of coke, gas also is produced. If the price of the coke is not to be too high, there must also be a market for the additional gas at a fair price.

In addition, all domestic grates installed in the future for burning solid fuel must be capable of burning gas coke efficiently. A step forward in producing grates and stoves to burn coke has already been made by the appliance manufacturers working in co-operation with the gas industry and in consultation with the Ministry of Fuel and Power and the Fuel Research Station of the D.S.I.R. On the basis of research work and tests by the Fuel Research Station, the Ministry prepares a list of appliances recommended for use in average dwellings. To be included in this list, the appliances must reach certain minimum standards of performance not only with coal but also with smokeless solid fuel. The appliances in this official list are included in a list published by the Coal Utilisation Council. Already about 4 million of the appliances have been installed in houses ; and the manufacturing capacity is fully equal to the demand and surpasses the rate at which increased supplies of smokeless solid fuels are likely to be available.

The policy for reduction of air pollution by domestic smoke must be, therefore, greatly to increase the production of suitable domestic coke, and to develop a balanced market for coke, gas, and electricity gradually to replace household bituminous coal. With suitably designed appliances, the efficiency with smokeless solid fuel is about one-third greater than with bituminous coal. The householder can thus afford to pay rather more for a ton of coke of the right quality than for one ton of bituminous coal.

Sulphur Dioxide

Appreciable reduction in the emission of sulphur dioxide from domestic chimneys is a very difficult problem. On average, British coals and cokes contain 1·5 per cent. of sulphur. When they are burned in domestic grates about 80 per cent. of the sulphur is discharged as sulphur dioxide. Replacement of coal by coke will only reduce the emission of sulphur dioxide if the quantity of coke burned is less than that of the coal it replaces. It is unlikely that such reduction, if any, would be more than 20 per cent. The concentration of sulphur dioxide in the gases from domestic chimneys, owing to the high dilution with air, is only 3 or 4 parts per 100,000 ; and there is little prospect of removing the sulphur at reasonable cost.

In so far as the bituminous coal is replaced by gas and electricity, there will be a corresponding reduction in sulphur emission from domestic chimneys. Replacement by electricity transfers the sulphur emission to the power station chimneys, but the discharge will be at a much greater height above ground level ; and there are much better prospects of developing practicable methods of removing and recovering sulphur from the chimney gases of industrial installations burning large quantities of fuel.

Warmth and Comfort in Dwellings

by

J. B. Dick

This paper will deal with some of the problems which are encountered when designing dwellings in which reasonable standards of warmth and comfort can be attained in winter.

The period over which heating is required in the South of England extends roughly from October to April. The mean outside temperature during this period is about 42° F., so that if we are to reach the comfort zone, the room temperatures must on the average be raised by rather more than 20° F. The rate at which heat must be delivered in the

dwelling to achieve such a temperature difference will depend on the heat losses from the structure either by conduction through the external walls, the windows, roof and floor ; or by ventilation replacing heated air by cold air from outside. At the Building Research Station we have been studying these heat losses both in the laboratory and in occupied experimental houses, and I should like to tell you something of this work and outline some of the conclusions which have been reached.

Factors Affecting Construction

Consider first of all the losses by conduction. At the Building Research Station we have for a number of years been measuring the rates of heat loss through different wall and roof constructions. For these measurements the construction under test forms the exposed side of a room which is maintained at a temperature of 65° F. The other sides, which are well insulated, are surrounded where possible by guard spaces at the same temperature. The rate of heat input required, corrected if necessary for any small heat losses through the other sides of the room, then gives the rate of heat loss to outside through the construction being tested. The results of such measurements are expressed in terms of the thermal transmittance, or U value, of the construction ; this is the rate of heat loss in British Thermal Units, per hour, per square foot for a difference of 1° F. between the air temperatures on the two sides of the specimen. Some typical values for walls and roofs are given below.

Walls	9-inch solid brick	U = 0·43
	11-inch cavity brick	U = 0·30
	11-inch cavity, outer leaf brick, inner leaf light-weight concrete	U = 0·25
	glazing	U = 1·0
	double glazing	U = 0·5
Roofs	pitched roof, tiles on battens, plasterboard ceiling	U = 0·42
	same with 4 inches glass wool laid between joists	U = 0·08

These values of heat transmission are available for a wide range of constructions, so that given the temperatures maintained in a building, an estimate can be made of the heat loss by conduction during a winter. With full central heating where an air temperature of say 65° F. is maintained throughout the heating season, a straightforward comparison can be made of the fuel costs with different grades of insulation, and an economic balance can be struck. In the more usual case where expenditure on heating is limited, another factor which must be considered is the level of temperature which will be maintained ; when the insulation is improved, the lower cost of heating will lead to the adoption of higher temperatures. This effect of the cost of heating was directly shown in an investigation made in eight houses at the Building Research Station. Measurements of fuel consumptions and temperatures in the houses were made over a period of four years, during which the cost of heating was varied by subsidising the fuel to different extents. It was found that when there was no subsidy on the fuel the houses were heated to about 11° F. above the external temperature, whereas with a subsidy of two-thirds, the temperature difference rose to about 18° F. Our evidence suggests that with partial heating rather less than half the potential saving in fuel is obtained, the remainder being used to provide a higher standard. This may be very satisfactory to the occupants who will have temperatures much nearer those recommended by the physiologist, but it does mean that it is more difficult to justify additional expenditure on better insulation in terms of the expected reduction in running costs. Taking into account the present restraints on capital expenditure, it will be seen that the emphasis in low cost housing must be on the provision of improved insulation with little or no extra expense.

As an example of such improvement consider the progress made in the insulation of walls. Before the war, many dwellings were built with 9-inch solid brick walls with U value of 0·43, though the use of the cavity brick wall with value of 0·30 was becoming established. This cavity construction was slightly more

expensive but avoided moisture penetration through the wall and had, as we have seen, improved insulation. After the war, the cavity brick wall was widely adopted and recently there has been increasing use of a cavity wall with an outer leaf of brick and an inner leaf of lightweight concrete. This construction has a U-value of 0·25 and is in fact slightly cheaper than the all-brick construction.

The heat loss by ventilation from a dwelling can also be of importance. In our experimental houses we measured the ventilation rates by introducing a tracer gas into the rooms and then recording the rate at which the concentration of the gas decayed. We found that on an exposed site the average rate of air change in 20 occupied houses was about 2½ per hour ; in 8 other houses on a sheltered site the average was about 2 per hour. In both cases there was an increase of about 1 air change per hour over the rate in the closed unoccupied but heated houses ; this was due to opening of windows and doors. The rate of heat loss caused by ventilation was similar to that by conduction. There is certainly much that can be done to improve the fit of windows and doors and still have adequate ventilation.

We have considered insulation and ventilation in relation to the provision of desired air temperatures in dwellings. These factors can also affect comfort in the home. Poorly insulated walls, roofs and floors besides involving excessive heat loss, also cause discomfort because of the low temperature surfaces which they present to the body. The increased rate of heat loss by radiation from the body can be compensated to some extent by the use of higher air temperatures, but as Dr. Bedford has pointed out, the combination of cold wall-warm air does tend to produce sensations of stuffiness and there is thus a limit to this compensation. It is of interest to consider the internal surface temperatures to be expected with different grades of insulation. For instance, when the outside air temperature is around 30° F., with a 65° F. air temperature inside, the inside surface of a 9-inch brick wall will be about 54° F. ; that of an 11-inch cavity brick wall 58° F. ; and that of an 11-inch cavity wall with lightweight inner leaf about 59° F. The inside surface of glass will be about 40° F. ; with double glazing or double windows the temperature will be raised to about 53° F. Thus the adoption of better insulation not only reduces the rate of heat loss from the house but also reduces the radiant heat loss from the body and makes a more comfortable environment possible. The adverse effects of ventilation on comfort are of course the draughts which may be caused ; much can be done to reduce these by applying weatherstripping, especially to any gaps through which cold air can enter at low level.

Performance of Heating Systems

The first requirement of a heating appliance is that it should be efficient in its use of fuel. It is also important to ensure that the heat delivered into the house is distributed to provide comfortable conditions, and it is this aspect which will be considered here. In particular, as Dr. Bedford has indicated, it is important to avoid the warm head-cold feet sensation which can be caused by too large a temperature difference between head and floor level. These temperature gradients are caused partly by cold floors which chill the air in contact with them ; by convection currents dropping down cold walls and windows and forming a pool of cold air at floor level ; and also of course by the rise of heated air from hot surfaces on appliances. As we have seen, the cold floor can be improved by additional insulation. The downward convection from cold surfaces can similarly be reduced, and can also be countered by the upward convection from suitably placed heaters. For instance, radiators or tubular heaters can be placed under windows ; or alternatively skirting board heating using circulated hot water can supply upward convection around the periphery of the room. Another method is to use floor heating in which hot water is passed through pipes embedded in the floor. This method of distribution gives comfortable conditions with cool head-warm feet ; the downward convection currents from windows are quickly lost in the general turbulence set up by the heated floor. Heated ceiling panels are also used ; these only produce appreciable temperature gradient in the first few inches beneath the ceiling. The

warm air method of heating has been used in recent years. Air is drawn from a room, heated and then blown back into the room. To avoid large temperature gradients with this system, the heated air should be delivered at the lowest possible level and should be distributed over a wide angle ; a high rate of air flow with a fairly low inlet temperature should also be used.

The heating systems just described are mainly used with full central heating. Not everyone can accept the high capital and running cost involved, and I should like to discuss now the most common form of heating, the open fire. It is worth noting that even in houses with full central heating there is often an open fire in the main living space.

The main fault with the open fire in the past has been the excessive volume of air drawn up the flue. With an internal door open, the rate of air flow can approach 12,000 cubic feet/hour. With the door shut, the rate of air flow is reduced to about 6,000 c.f.h., this air entering through the gaps around windows and doors ; the total area of these gaps is often at least 30 sq. ins. These flow rates are well above the 2–3,000 c.f.h. which will provide adequate ventilation, and can be brought nearer this level by incorporating a restriction in the throat of the fire or the flue itself ; the air flow is then limited whether or not the door of the room is open. The reduced flow also causes higher flue temperatures and a greater heat recovery from the flue back into the building ; to take full advantage of this heat gain, the flue should be on an internal wall. Flue or throat restrictors in various forms are now on the market and are intended for use in existing houses ; there are also new appliances which incorporate a restrictor. This development can hardly be presented as a new development in building science. Dampers and adjustable canopies were in common use fifty years ago but these unfortunately were sacrificed in the streamlining of modern fireplaces and surrounds. An alternative method of reducing the amount of heated air withdrawn from a room by an open fire, is to supply air directly to the fire through a small duct from outside. This requires well-fitting windows and doors if most of the air for the fire is to enter through the duct ; it should preferably be combined with a flue restrictor. Another improvement with the open fire has been the provision of a convector jacket, so that heat conducted through the fireback is returned into the room and not allowed to soak into the setting and the surround. It should be noted that with all these open fires a higher efficiency can be obtained by burning coke instead of coal.

The open fire is often attacked on grounds of inefficiency ; figures of 10 per cent. efficiency are often quoted. This has not been our experience in our house heating experiments where we have found that with an internal flue some 40 per cent. of the heat content of the fuel burned is delivered into the house ; some of this comes into the bedrooms and provides useful background heating. Furthermore we have found that those who are unable or not prepared to spend much on fuel get an acceptable standard of comfort at a lower running cost with an open fire than with, say, hot water radiators. This is mainly because the high temperature radiation from the open fire makes comfort possible with a lower air temperature than with conventional radiators which, in spite of their name, provide heat mostly by convection. It thus appears that particularly with recent improvements in design and the increasing use of coke that on technical grounds there is still a future for the open fire.

Acknowledgments

This paper is published by permission of the Director of the Building Research Station, Garston, Watford, Herts.

SCIENCE AND THE HERRING FISHERY[1]

by

R. S. GLOVER

For thirty years Professor Hardy has been contributing to our knowledge and guiding and encouraging other people engaged in research on the herring. It is most appropriate therefore that, during this meeting in his department, I should describe some recent extensions of his work.

Professor Hardy's research on the herring stems from his interest in the planktonic organisms which the herrings eat. Naturalists long ago expressed their opinion that shoals of herring or mackerel were often found near concentrations of their planktonic food. And fishermen believe that the colour and opacity of the water can be used as an indication of abundant animal plankton where herrings may be expected and that 'slimy' or 'stinking' water indicates organisms which the herrings avoid.

Professor Hardy set out to test these beliefs and, with his colleagues Dr. Lucas and Dr. Henderson (1936), he showed that herrings were indeed more likely to be found where their food was abundant. This confirmation was achieved with the help of fishermen who took samples of plankton when they arrived on the fishing grounds. The samples were taken with the Plankton Indicator which Professor Hardy designed in 1922.

The Hardy Plankton Indicator is a simple plankton collector which is towed at full speed behind a fishing vessel.[2] The plankton is collected on a fine silk disc which can be inspected by a fisherman using a lens or it can be returned to the laboratory for detailed examination.

Professor Hardy intended that, when fishermen had learned to distinguish between the different kinds of plankton, they should use the Indicator to sample the water and so be warned away from unprofitable localities and guided into areas in which there were likely to be herrings.

Although the Indicator has been little used as a fish-finder, in the hands of commercial fishermen it has proved to be a most useful tool for research on the environment of the herring. Every year since 1947 fishermen aboard herring drifters, working from Fraserburgh on the north-east coast of Scotland, have collected samples of plankton for the Edinburgh laboratory of the Scottish Marine Biological Association. This work, on the plankton of the herring-fishing grounds and on the feeding habits of the fish, is part of an extensive programme of ecological research on the herring which is shared between the Edinburgh laboratory and the Scottish Home Department's laboratory at Aberdeen.

Since this is to be a 'non-specialist' paper, and because my time is limited, I shall mention only one or two aspects of this many-sided programme. I want to demonstrate the important part which is played by fishermen and this can best be illustrated if we first summarise ecological techniques as being of three kinds.

I. *Measuring the abundance and distribution of the animal one is studying*—taking counts at convenient intervals of time and space.

II. *Measuring the environment*—the physical and chemical properties of the air, soil or water in which the animal lives and the nature and abundance of the other animals and plants which form what Professor Hardy has called the animate environment.

III. *Investigating the relationship between I and II*—involving, for example, physiological and morphological investigations on the animal itself and the study of its stomach contents.

[1] Short version of a paper read before Section D (Zoology) at the Oxford Meeting of the British Association on September 8, 1954.

[2] For a description of the various models of the Hardy Plankton Indicator, see Glover (1953).

The first two may be difficult to achieve at sea where the animals and plants are hidden in a constantly varying and shifting environment. The area which it is necessary to survey is often too great for adequate sampling from a single research ship. But if the animal one is studying is the subject of a commercial fishery, then the fishing boats may become a fleet of research ships.

Scottish fishing vessels, acting as research ships, are fulfilling the three major requirements of ecological research listed above.

I. With their nets and through the size of their catches the fishermen count the fish and so obtain the measure of distribution and abundance needed for the first of the three techniques. Every day some 200 skippers from Fraserburgh and Peterhead tell us where they have fished and how many herrings they have caught.

II. Sampling the environment, which was the second requirement, is normally a specialised job ; the collection of seawater for chemical analysis and for measurement of temperature is done from research ships of the Scottish Home Department.

But, thanks to the Hardy Plankton Indicator, fishing vessels can easily provide samples of the biological environment, or at least the most important part of it, the plankton.

III. Finally, selected fishermen supply small samples of fish from their daily catches so that we in Edinburgh can investigate the stomach contents of the herring; so that Dr. Fisher of Reading can study the Vitamin A and fat content, and Mr. Parrish and his Aberdeen colleagues can study age, weight, length, sex and make other biometric analyses. This fulfills requirement III, the provision of material for a study of the nature of the relationship between the herring and its environment.

Off the north-east coast of Scotland the drift-net fishing lasts from May to September. The fishing boats, wooden vessels 60 to 80 feet long and propelled by diesel engines, leave the harbour every afternoon for the fishing grounds from 10 to 100 miles offshore.

Each vessel carries from 60 to 80 nets which are thrown over the side just before dark ; this we call ' shooting the nets ' and so a catch of herrings is often called a ' shot.' When the last net is thrown over the side the engine is stopped and the boat lies, stem into the wind, drifting slowly through the water (Fig. 1). The nets are tied together, weighted by a heavy rope at the bottom and suspended by corks and buoys at the top. Hanging vertically, 5 to 15 fathoms down, there may be 1½ miles or more of netting attached to each boat.

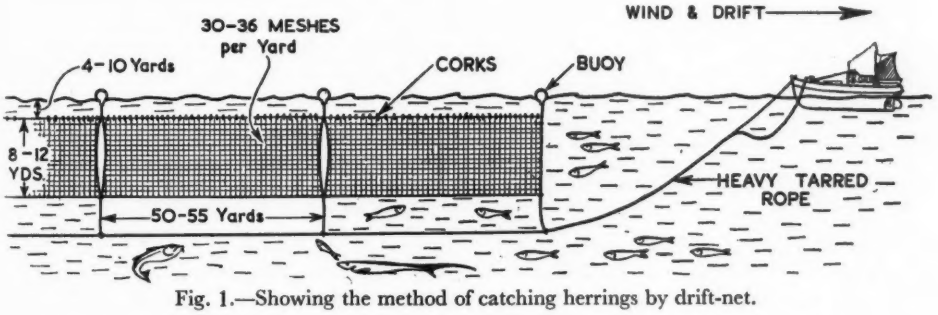


Fig. 1.—Showing the method of catching herrings by drift-net.

This drifting phase lasts from three to five hours of the night when herrings may be expected to rise from the deeper water and to swim into the meshes which, as Hartwig (1861) said,

> ' are exactly calculated for the size of the herring, wide enough to receive the head as far as behind the gill-cover, but not so wide as to allow the pectoral fins to pass. Thus the poor fish, when once entangled, is unable to move backwards or forwards and remains sticking in the net, like a bad logician on the horns of a dilemma, until the fisherman hauls it on board.'

At about one o'clock in the morning the nets are hauled ; each net is lifted over the

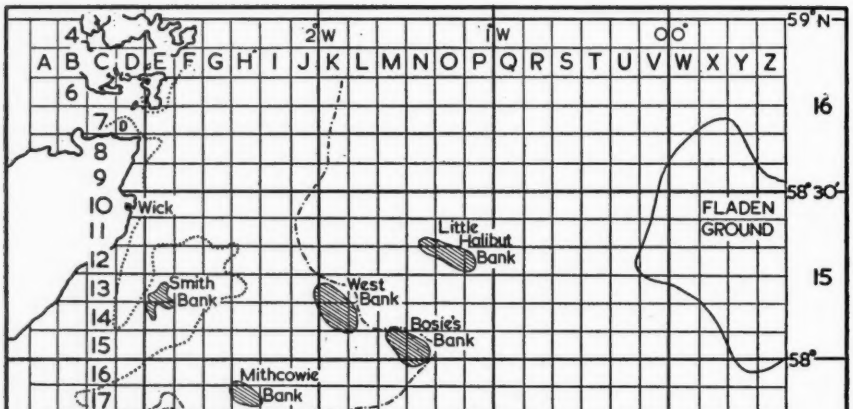


Fig. 2.—Chart, showing the area from which samples of herrings and plankton have been collected by fishermen. The chart has been divided into squares measuring 5 × 5 miles.

side by hand with its load of herrings hanging helplessly by their gill covers. The fish are shaken out and immediately brought back to harbour to be discharged in the freshest condition the morning after they have been caught. Five days a week, from the Scottish ports, the boats put to sea to shoot and haul their nets.

The catch is measured in crans. A cran is usually between 900 and 1,200 fish, depending on their size, and a fishing boat will expect to catch 15 to 20 crans, on the average, in each night's fishing, say 14,000 to 25,000 fish; a boat may, quite easily, catch as many as 180,000 herrings in one shot.

The area from which our samples are taken by the fishermen is shown in Fig. 2. When a research ship is used for a survey, the work is planned so that samples are

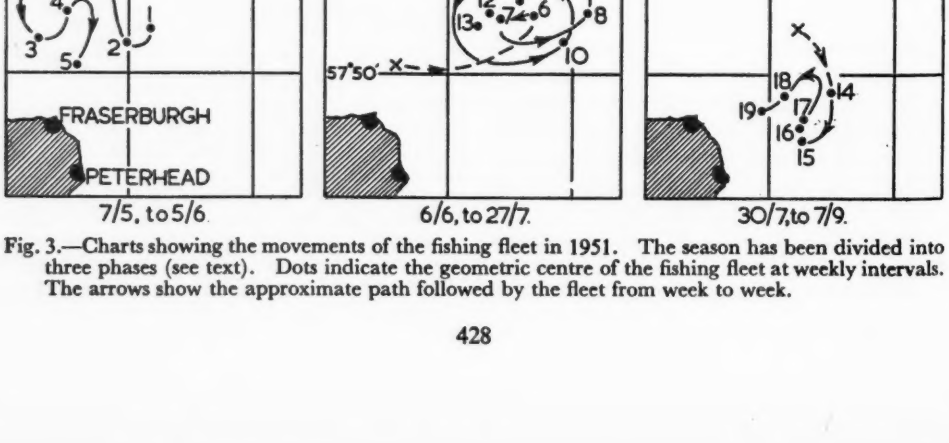


Fig. 3.—Charts showing the movements of the fishing fleet in 1951. The season has been divided into three phases (see text). Dots indicate the geometric centre of the fishing fleet at weekly intervals. The arrows show the approximate path followed by the fleet from week to week.

taken at stations which are suitably spaced and which cover the whole area from which material is required.

But our samples of fish and plankton are taken from fishing vessels on the fishing grounds and, unlike the research ship stations, the boats are not suitably spaced and they do not explore the whole area in which we are interested. Sometimes they fish so close together that their lights at night give the appearance of a large town afloat. And sometimes the fishing fleet is so dispersed that, standing on the deck, it is difficult to believe there are other ships at sea.

But although, from day to day, there is an erratic restless movement of fishing vessels, dispersing and searching then aggregating and exploiting, over the season there is a fairly regular pattern of fishing which is repeated in each year. This pattern is typified by the results for 1951, illustrated in Fig. 3. By plotting the distribution of the boats during each week it is possible to calculate the theoretical centre of the fleet. In Fig. 3 these weekly centres are numbered 1, 2, 3, etc., in date order ; arrows are inserted to show the approximate path followed by the fleet.

In each year the fishing could be divided into three phases :

Firstly. In May and early June there was a westerly fishing around the shallow banks shown in Fig. 2.

Secondly. In late June and July there was a central and eastern fishery over deeper water.

Thirdly. In late July and August the fishing fleet shifted, week by week, southwards and westwards towards the coastal region where the herrings spawn at this time each year.

This pattern might result from traditional fishing lore, but our study of the day to day movements of the fishing fleet suggests that the fleet is a fairly efficient searching unit. Is it reasonable to assume, therefore, that the movements of the fishing fleet reflect, to some extent, the migration of the shoals of herrings ? This is the reason for our interest in fleet movements.

The movements of the boats may suggest patterns of migrations of the herrings *within each season.* But if we compare the areas of productive fishing in *different years,* we see another pattern of movement.

So that we can easily deal with the material, the chart in Fig. 2 has been divided into squares of five-miles side. In Fig. 4 those squares with an average catch per shot of over 40 crans have been used to indicate the localities in which the most successful fishing occurred. It is clear that the best fishing results came from the north in 1947 and a little further to the east in 1948 and 1949. The high catches in 1950

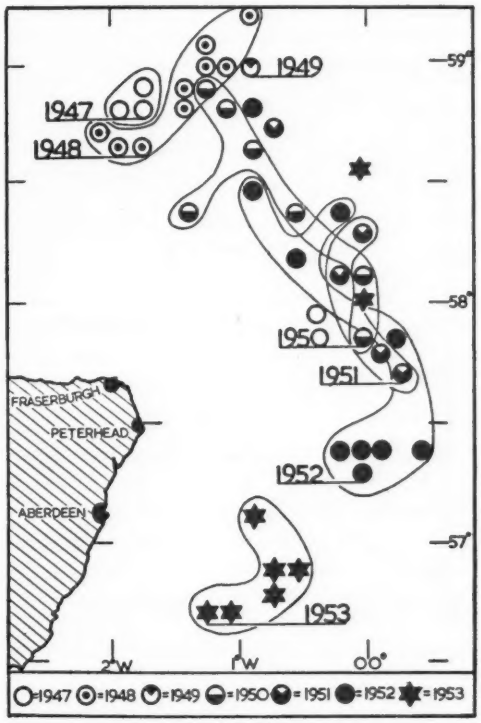


Fig. 4.—Chart showing the locality of the most productive fishing from 1947 to 1953. The symbols indicate those five-mile squares (see Fig. 1) which yielded an average catch, during each season, of more than 40 crans per shot.

were found in a long narrow band, and further to the south-east ; more to the south in 1951 and further south again in 1952. In 1953 the best fishing was about 140 miles to the south of the high catches in 1947. Further evidence is provided by figures published in the 'Annales Biologiques' of the International Council for the Exploration of the Sea ; these figures show that Dutch fishing vessels, working a little further offshore, also took their best catches progressively further south in each year.

It looks, therefore, as though the herrings have migrated southwards—or rather the shoals have arrived on the fishing grounds a little further south each year.

We first noticed this effect when we were assessing the validity of sampling from fishing vessels but recently the matter has assumed a much greater importance. The herring fishery around the Shetlands, some 150 miles to the north of Fraserburgh, has failed. This could result from poor recruitment of fish to the Shetland stocks,

1947	1948	1949	1950	1951	1952	1953	1954	YEAR
29	27	16	14	14	20	12	12	SHETLAND
13	16	9	12	12	21	20	21	FRASERB'H
13	14	11	12	13	25	24	26	PETERHEAD

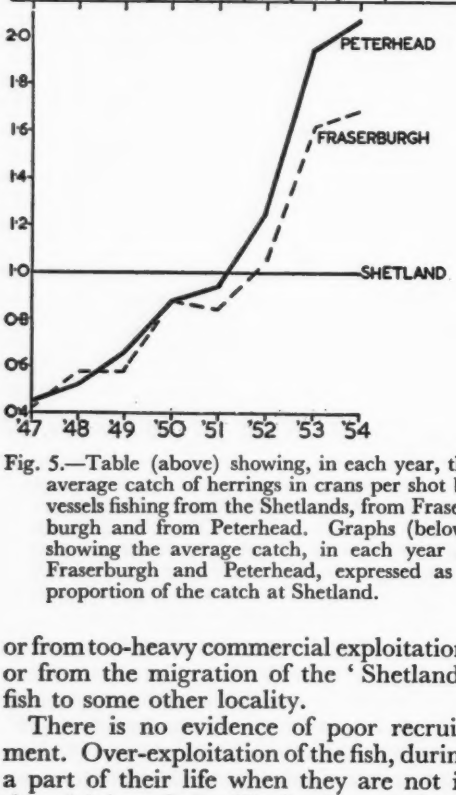


Fig. 5.—Table (above) showing, in each year, the average catch of herrings in crans per shot by vessels fishing from the Shetlands, from Fraserburgh and from Peterhead. Graphs (below) showing the average catch, in each year at Fraserburgh and Peterhead, expressed as a proportion of the catch at Shetland.

or from too-heavy commercial exploitation, or from the migration of the ' Shetland ' fish to some other locality.

There is no evidence of poor recruitment. Over-exploitation of the fish, during a part of their life when they are not in the vicinity of the Shetlands, remains a possible explanation. But I have just presented the evidence for a southerly migration of herrings in a neighbouring fishery. If this was an extensive phenomenon can it have taken the fish away from the Shetlands? The results presented in Fig. 5 suggest that this may indeed be the explanation of the collapse of the commercial fishery in the Shetlands, an event which may have serious economic consequences to those islands.

Fig. 5 shows, in tabular form, the average catch of herrings by vessels fishing from the Shetlands, from Fraserburgh and from Peterhead. At first, catches were highest in the Shetlands, but during the last three years the highest catches were landed at Peterhead, the most southerly port of the three. To remove over-all fluctuations in different years, the average catch at Fraserburgh and at Peterhead has been divided by the Shetland catch in each year. The sharply sloping lines in Fig. 5 therefore express the Fraserburgh and Peterhead catches in proportion to the catch at Shetland. Peterhead catches were less than half as big as those landed in the Shetlands in 1947 and about twice as great in 1954.

It is clear that the changing success of the ports has been a steady reciprocal process throughout the eight years. The Shetland fishery collapsed whilst the more southerly ports prospered. And the most southerly port, Peterhead, has been gaining progressively on its old rival, Fraserburgh, during the last three years.

A closer inspection of the Shetland fishery reveals that the drop in catches was most marked in the latter part of each season. In 1947 and 1948 high catches were taken from May to August, but, in 1953 and 1954, successful fishing was restricted to May and early June. It is impossible to assess the full significance of this change until we have studied the composition of the herring stocks at the different ports. Is it reasonable to suppose that fish which arrived at the Shetlands each year moved southwards, during each season, to the Fraserburgh and Peterhead area ; and that they moved southwards at a progressively earlier date ?

Now, when an ecologist finds himself asking questions of this kind he must consider the obvious question. Has there been any parallel change in the nature of the environment ?

Dr. Tait (1937) of the Aberdeen laboratory has plotted the surface currents of the northern North Sea. He shows oceanic water mixed with some coastal water flowing from north to south across the

herring fishing grounds. This stream brings with it plankton which is characteristic of mixed oceanic and North Sea water. These plankton forms are known as ' indicator species ' ; by the recognition of such species it is possible to identify water, not by any physical or chemical analyses but by the plankton which it contains.

A small planktonic mollusc, *Clione limacina*, is an indicator in the North Sea of the mixture of coastal and oceanic water from the north. Fig. 6 shows the average

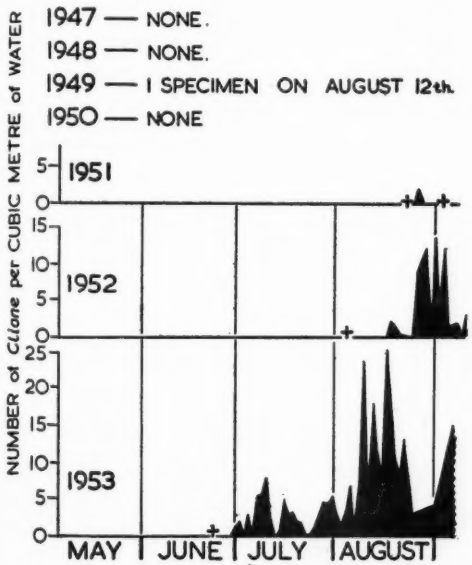


Fig. 6.—Graphs showing, day by day, the average number of *Clione limacina*, per cubic metre of water, in samples collected by fishermen using the Hardy Plankton Indicator on the Fraserburgh fishing grounds.

number of *Clione*, in a cubic metre of seawater, in samples taken by the fishermen with the Hardy Indicator. In the first four years they caught one individual in the Indicator (and some were found in herring stomachs). In the last three years it has appeared in increasing quantity in the food of the herrings and it has not only increased in numbers in the sea—the date of its first appearance has become progressively earlier. At the time of writing, the complete results for 1954 are not available, but it is known that *Clione* arrived at least as early as in 1953 and probably in greater abundance. Other organisms which are associated with oceanic conditions have also increased in abundance in recent years. Using biological evidence, therefore, it appears that some characteristic of oceanic water may have arrived in the North Sea in greater quantity and it may have moved southwards at a progressively earlier date during the same period as the southerly shift of fish which I have described.

Is it reasonable to relate some quality of oceanic water to the distribution of the herring? There is no real evidence but there are other circumstances which point in the same direction.

My colleagues in the Edinburgh laboratory study the plankton along great traverses across the North Sea and into the Atlantic. They get their plankton samples with another of Professor Hardy's inventions, the Continuous Plankton Recorder, which is towed by passenger and cargo ships steaming on their regular passages. As a result of over ten years of sampling with the Recorder we know that planktonic indicators of warm oceanic water are carried southwards into the North Sea in a regular and well-defined manner each year.

Fig. 7a shows the typical distribution, month by month, of these planktonic indicator species ; *Clione* and many other organisms show a similar pattern.[1] Mr. Rae described, to the Newcastle meeting of the British Association in 1949, the close parallel between this pattern and the times and places at which herrings spawn. This coincidence is illustrated in Fig. 7b which shows the herring spawning grounds ; the same north to south succession, from August to December is clear in both parts of Fig. 7.

The staff of the Edinburgh laboratory are making a special study of the biological effects of such influxes, from the north, of mixed water, identified as such by its characteristic plankton. Here we are supposing that some quality of oceanic water, or of the mixture of oceanic and North Sea water, may exert a vital influence on the distribution of the herring. Perhaps this attribute of mixed water encourages the shoaling of herrings and therefore results in successful fishing. If, as the abundance of *Clione* suggests, the oceanic quality

[1] For examples, see Rae and Rees (1947), Marshall (1948) and Glover (1952).

arrived from the north earlier in each year the fish may have moved southwards earlier with it and so effected the translation of successful fishing away from the Shetlands and towards Peterhead.

But what quality of the water should we look for? Temperature, chemical content, plankton, perhaps some constituent of the water as yet unrecognised—maybe something like the external metabolites which Dr. Lucas (1947) has discussed.

In following up this line of reasoning the use of biological characteristics to define water conditions may have an advantage over the more rigid definitions of salinity and temperature.

This is very loose speculation—but let me remind you that Dr. Harvey (1950) has demonstrated the importance of micro-constituents of sea-water, particularly organic substances, in the growth of phytoplankton.

And Dr. Wilson (1951) has shown that there is some unknown growth factor which is present in water from the Celtic Sea and absent from English Channel water. The two types of water which Wilson tested were recognised by the presence in one of a planktonic indicator of oceanic water, *Sagitta elegans*, and in the other of *Sagitta setosa* which is an indicator of North Sea water. Larvae of *Echinus* and other invertebrates survived and developed in '*elegans*' water but they died or became abnormal in '*setosa*' water. And a mixture of the two waters had the growth-promoting properties of '*elegans*' water.

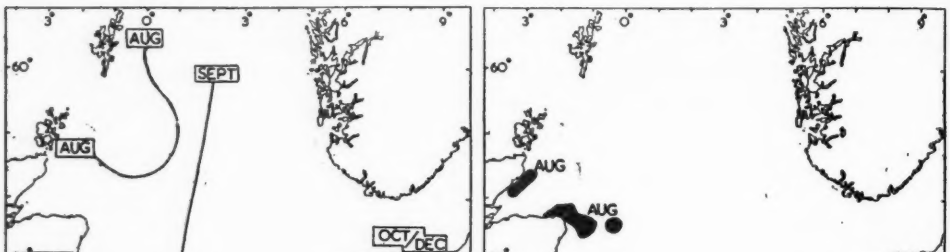


Fig. 7.—(*a*) Chart showing, month by month, the southern limit of the distribution of planktonic species indicative of the flow of mixed water from the north. This is a typical picture derived from Continuous Plankton Recorder results.

(*b*) Chart showing the localities and dates of the major incidence of the spawning of herrings.

In such a brief summary I have had to select one very small aspect of the work which the Edinburgh and Aberdeen laboratories are conducting over a wide field of research on the herring. I have said nothing of the feeding of the herring or of its distribution in relation to its planktonic food. I might have mentioned the simultaneous collection at many depths, from research ships of the Scottish Home Department, of water for chemical tests, of temperature records and of plankton. Echo-sounders are used to plot the distribution of herrings in relation to these physical, chemical and biological factors.

In most ecological research, sampling methods are carefully designed before the work is started. In our work the sampling methods have been laid on by the fishing boats. This means that we have had to study the fishing fleet as a sampling unit. I have chosen my examples to-day from this aspect of the work to demonstrate that our ecological studies of the herring are inseparable from an ecological study of the commercial fishery.

I would like to emphasise the co-operative nature of the programme, involving planktologists from Edinburgh, engaged on ecological problems, fishery scientists from Aberdeen who must keep one eye on biology and the other on the fishing industry—and the fishermen of north-east Scotland.

Professor Hardy, when he founded the Department of Oceanography at Hull in 1931, felt that fundamental research on marine plankton must contribute towards a better knowledge of the fisheries, in so far as all fish ultimately depend on the plankton for their food. I believe that by this bigamous marriage of fishermen, fishery biologists and planktologists we may hasten the achievement of Professor Hardy's target.

Marine ecology is fascinating in its many and often unexpected ramifications and the ecologist who is privileged to work in a joint programme of the kind I have described not only draws on a wide variety of material from fishing vessels and from research ships but, whilst he pursues his own personal interests, he knows that his work is never far away from the practical problems of an industry.

Indeed all the points at which the industry may look to science are questions about ecology. For instance :

Are we fishing in the most profitable locality ? This is a question about the distribution of the fish and the factors which affect that distribution.

Do we use the most efficient type of net to catch the fish ? The answer is clearly dependent on knowledge of the ways in which fish shoal, the depth and extent of these shoals and the factors which cause fish to aggregate and disperse.

Is the stock of fish increasing or decreasing—to what extent will it stand the depredations of the fishery ? This is asking the ecologist to conduct a population study and to assess the various sources of mortality.

Is the excessive fishing at A likely to destroy the stock which is fished elsewhere at B ? Here the ecologist must define the stock of fish and their migrations. He must decide whether the fish belong to one or to several racial types and whether different types intermix.

The history of the herring fishery is the history of alternating economic depression and financial plenty, resulting from the apparent disappearance of fish from one locality and their appearance in another place. The ecologist must decide whether these changes result from fluctuations in the strength of local stocks, or from mass migrations. Both explanations pose a further question. To what extent are such phenomena attributable to fluctuations in the environment ? Having answered such questions the biologist must examine the possibility of forecasting future fluctuations so that the fishing industry may be forewarned.

All these points are surely obvious but I mention them to remind you of the challenge to ecological work which the fisheries offer and to remind you also, as Michael Graham (1943) has said, that

'. . . organised marine biology was conceived by fishermen and it would be a flimsy thing without them and their problems.'

References

Glover, R. S. (1952) : 'Continuous Plankton Records : The Euphausiacea of the North-Eastern Atlantic and the North Sea, 1946–1948,' *Hull Bull. Mar. Ecol.*, **3**, 23.

— (1953) : 'The Hardy Plankton Indicator and Sampler : A Description of the Various Models in Use,' *Bull. Mar. Ecol.*, **4**, 26.

Graham, M. (1943) : 'The Fish Gate,' London, Faber and Faber.

Hardy, A. C., Henderson, G. T. D. and Lucas, C. E. (1936) : 'The Ecological Relations between the Herring and the Plankton investigated with the Plankton Indicator,' Parts I, II and III, *Journ. Mar. Biol. Assoc.*, **21**, 1.

Hartwig, G. (1861) : 'The Sea and its Living Wonders,' London, Longman, Green, Longman and Roberts.

Harvey, H. W. (1950) : 'On the Production of Living Matter in the Sea off Plymouth,' *Journ. Mar. Biol. Assoc.*, **29**, 1.

Lucas, C. E. (1947) : 'The Ecological Effects of External Metabolites,' *Biol. Rev.*, **22.**

MARSHALL, N. B. (1948) : ' Continuous Plankton Records : Zooplankton (Other than Young Fish) in the North Sea, 1938–1939,' *Hull Bull. Mar. Ecol.*, **2**, 13.

RAE, K. M. and REES, C. B. (1947) : ' Continuous Plankton Records : The Copepoda in the North Sea, 1938–1939,' *Hull Bull. Mar. Ecol.*, **2**, 11.

TAIT, J. B. (1937) : ' The Surface Water Drift in the Northern and Middle Areas of the North Sea and in the Faroe-Shetland Channel,' *Fisheries, Scotland, Sci. Invest.*, 1937, 1.

WILSON, D. P. (1951) : 'A Biological Difference between Natural Sea Waters,' *Journ. Mar. Biol. Assoc.*, **30**, 1.

LEONARDO DA VINCI[1]

by

DR. F. SHERWOOD TAYLOR

As a painter Leonardo da Vinci ranks among the few who are second to none : as a man of science he was the first of his time, notable, not only for his studies in anatomy and his mechanical inventions, but for the pregnant dicta in which he anticipated the future progress of every science. Nor was this all, for he was noted for his music, now lost to the world.

What manner of man was this ? To excel in more than one activity is very rare, and as years have gone by and the sciences have grown, it has become rarer. Leaving aside such semi-legendary figures as Imhotep and Pythagoras, we find the first of our universal men in Aristotle, biologist, encyclopaedist of science, founder of logic, politics, ethics and aesthetics. He took all knowledge for his province and systematised it into an intelligible scheme. Yet Aristotle's work all lay in the faculty of knowledge and reason, whereas Leonardo excelled not only in the field of knowledge but also in that of creative work. There were many great mediaeval encyclopaedists, Avicenna, Djabir, Rhazes, Gerbert, Robert Grosseteste and Albertus Magnus, who set out, if not to know everything, at least to attain such knowledge as should form in their minds an image of the whole world. They sought to be universal in knowledge, but generally they did not attempt to make themselves masters of the fine arts—except perhaps of poetry ; here we may think of Dante, as a poet of towering stature and yet intensely aware of all that the men of his time thought worthy to be known, or of Thomas Aquinas, theologian and philosopher and if he be the author of the Office of Corpus Christi, no mean poet.

Leonardo's age, the close of the fifteenth and beginning of the sixteenth century, was indeed that of the universal man, and abounded in men who took all knowledge for their province, and excelled in at least the literary arts. Pico della Mirandola, Aeneas Sylvius Piccolomini, Ficino, Cornelius Agrippa, Cardan, Rabelais, may serve as examples : but, with few exceptions, the tendency of the age was literary, learned and speculative : its writings intolerably wordy, loaded with quotations, serving but to display the writer's learning, and full of metaphysical and occult speculations which found little or no issue in human affairs. For such Leonardo had no small contempt : nearly all that he writes is brief and concerned with practical directions for *doing* something, whether in art or technology. Nearer to Leonardo, however, were some that excelled in the plastic or the graphic arts ; such were Alberti, whose work covered architecture, painting, mathematics, mensuration and who studied the canon of proportions of the human figure ; Albrecht Dürer, only less great than Leonardo in the graphic arts, and also concerned with the sciences of measurement and perspective ; and Andrea del Verrocchio, Leonardo's master, who was a man of the widest range of interests. After Leonardo's time, this universality became rarer : we may recall Francis Bacon, lawyer, statesman, essayist and first founder of the new science ; his co-founder René Descartes was another, having made imperishable contributions to science and its method, to mathematics and to philosophy. Pascal, too, earned renown in the fields of science, philosophy, mathematics and religion.

From the time of the refounding of science down to the present day, the universal man has not only become rarer but has almost ceased to be an ideal. Benjamin Franklin was one who made a solid contribution to physics, and served his

[1] Address delivered to Section L (Education) on September 8, 1954, at the Oxford meeting of the British Association.

country as a statesman. But the only figure of these ages comparable with the great men I have named was Goëthe who, being one of the world's great poets, was yet interested in science and made significant contributions to it. Yet Goëthe's attitude to natural science proceeded by the intuition of very wide generalisations and analogies, which scientific method did not warrant, descending from them to theories which were sometimes brilliantly right, sometimes hopelessly wrong. Leonardo, in contrast, was always scientific in spirit, even though science had not then worked out its methods.

Seen against the background of all human history, Leonardo da Vinci, then, stands out, as no other, in the character of universal man : and it may be useful to set out at least the headings of his achievement.

First we must confess that we do not know Leonardo da Vinci. His biography is of the scantiest. We see and marvel at his achievements, but we rarely find an incident or passage that makes us recognise a fellow man.

Let us begin with the smaller task of asking ourselves what this great man lacked of universality ?—what had others that he had not ? First, Leonardo lacked of universality, in that he was homosexual and he had the defects as well as the advantages of that condition. The homosexual with an acute perception of aesthetic values, and a love of every field of art and literature is familiar to us : we are, I think, often surprised by his failure to make his mark in any of them. Leonardo was so great a genius that he could touch nothing without making his mark on it, but it may be that the inability to finish anything that is so characteristic of him is connected with this same homosexual dispersal of interests, as well as with his dissatisfaction with anything less than perfection. If he was not less universal for this, he was at least less typical.

Secondly, I would venture the statement that he was not a religious man. He painted religious subjects, but religion was the occasion for the lively portrayal of human and dramatic scenes, not an end. In his written notes he scoffs at formal religion and its ministers and though some passages show him to have been a believer in God as Author and Dispenser of all things, this was the background rather than the substance of his thought. The mystical, magical and occult were alike foreign to him, as to few others of his age.

His weakness was, in fact, that he was not very much interested in that part of the world that does not manifest itself to the senses : his strength that he was intensely aware of the sensible world, living and non-living.

It is perhaps no great thing for a man to know more than one science. What we must admire and seek to comprehend is Leonardo's ability to marshal all his faculties and equipment and so to *grasp* and *do* more than the man of lesser range.

In the so-called *Paragone* (Codex Urbinas 1270) Leonardo sets out his idea of the relation of painting to the other arts and to the sciences.

In this and other MSS. Leonardo treats the sciences as ancillary to the art of painting, but this statement is to be understood in a very lofty sense. The painting itself involved an actual *creation*, of an order far superior in dignity to any of the arts or sciences that preceded it. The artist was to be a creator, like God.

To this supreme synthesis, the sciences and arts were necessary. The supreme act of the artist was his expression of things and people, in such a way as to tell a more perfect truth than could be told by any science (which merely deals with an aspect of the whole) or by art alone. But since the artist's creation was to be in terms of natural objects—things perceived by the senses—it required the most perfect knowledge of these, and this knowledge could be gained only by the particular form of rationalised observations that we call science. We find then that Leonardo was continually trying to discover the significant detail of things. He was intensely concerned to be able to show objects as they really were : to express not only a superficial likeness, but to bring out their structure and form. But this was not the total of his intent, as it might have been that of a scientist, for obvious in all his drawings is the *love* of what he saw and drew. I can well believe the contemporary assertion that he bought caged birds to set them free and became a vegetarian so that no animal should be killed for him.

I do not think Leonardo regarded the sciences simply as handmaids of artistic expression, but he certainly regarded them as necessary to that expression, which otherwise could not attain truth. The sciences were to contribute to him, both the detail of what he was to paint and the means of painting it. The soul, for him as for all his age and those that preceded it, was the form of the body, that which made it what it was : through the representation of bodies it was therefore possible to represent souls. Leonardo seems to have spent much time in observing people about their work and sketching the faces and figures of different types—herein was something of science, but not of a science capable of being fully rationalised. But the body itself was of intense interest to him and we are all familiar with the wonderful anatomical drawings that he made, based on some thirty dissections. Here he gained the knowledge of the construction of the body, but he warns us that a picture is not to be an anatomical drawing : it should express the artist's conception, not show his prowess in anatomy. Nor was his anatomy to be dead anatomy : the mechanism of the body in action is his constant study. Man was the principal subject of his study : but the anatomy and forms of plants proportionately fascinated him, as did the nature and structure of the rocks.

In the same way he sought in the observation of nature the dynamic and structure of things. He did not, like Galileo, and Newton, seek mathematical laws of motion, but wide general analogies. He could compare the curling wisps of vapour with the eddies of water and these again with the curls of the hair ; these spiral and volute forms fascinated him, though he could not give a true explanation of them.

The representation itself, he tells us, was to be founded on the science of perspective and the optical principles of light and shade and he devoted long sections of his notes to these. He did not much, if at all, advance these sciences, for his mathematical equipment seems to have been rather scanty and he was throughout looking for the results useful to the artist rather than working out absolute principles. Yet we must never forget how little developed was the idea of natural science in his time. Leonardo clearly understood that a science must start from the experience of the senses and proceed by ' mathematical demonstration,' but in most of his work he was, in a way, by-passing the long road of demonstration of principles in order to come to results useful to his art.

Here then we see Leonardo's thesis, that the artist's creation was the supreme act, but could only come to a perfect birth through the knowledge of the sciences, which were not the means of that creation, but a means to it.

But does Leonardo's life and work as we know it confirm this ? In fact he painted very little, but spent a great deal of his time on the sciences, and especially on the subject of mechanical devices.

I am quite unqualified to decide, where experts disagree, as to the authenticity of the various paintings attributed to Leonardo. The Annunciation (Louvre) (1474) ; Lady with an ermine (1483) ; The Virgin of the Rocks (Louvre) (1483–9); The Last Supper (S. Maria della Grazie) (1495–8) ; Mona Lisa (Louvre) 1503 ; St. John the Baptist (Louvre) (1509–12) ; are confessed to be genuine. There are only two or three more which are even generally accepted, nor do many seem to have been lost during the succeeding centuries.

Painting was not his only art. He made numerous talented architectural drawings ; and many pages of his notebooks are devoted to his project for a colossal equestrian statue, which was modelled but never cast.

In contrast to Leonardo's small output of finished work there is an enormous corpus of drawings and sketches, preparatory to pictures, several of which he projected but never finished—or in some cases never began.

It seems obvious, and was noticed by his contemporaries that as Leonardo's life went on, he found himself less and less inclined to paint, though it does not appear that his powers had in the least diminished.

Our only clue to this reluctance is a contemporary's note that in 1500 (before the production of the Mona Lisa) he was working hard at geometry and was very impatient of painting—that he could not

bear to take up the brush : and again that when he ought to have been painting, he was giving himself up entirely to geometry, architecture and anatomy. We may think that his study of all the sciences revealed to him much that could not be expressed by the painter, and that he increasingly came to regard the knowledge and creation in natural science as an end in itself, not wholly to be expressed in the artist's vision.

His interests, indeed, were by no means confined to what could contribute to the fine arts. It is evident from his teeming notebooks that he gave as much attention to engineering as to the representational arts : that his scientific studies could issue in the creation, not only of the profound symbol that is a picture, but also in that of a useful mechanical contrivance, such as a military engine or a lathe. Indeed, when we follow his career from one Italian city to another, we do not find him in the capacity of a painter but of an engineer, concerning himself especially with hydraulic works.

From architecture, a natural pursuit for an artist, we find him turning to town planning, not only in the artistic aspect, but giving attention to such practical matters as water supply and disposal of sewage and rubbish. Hydraulic works, canals, sluices and the like fascinated him and he never tired of drawing the form of surging water. His military inventions were by no means amateurish, though most of them were too elaborate to have been put into practice. Especially fascinating and original is his work on flight, wherein he sets out to record the manner in which birds fly and to design a flying machine. Whether a large-scale attempt was made we do not know, but it is very probable that Leonardo made a model which flew. Indeed every kind of contrivance engaged his attention : he drew improved types of stills, and all manner of tools, machines for file-cutting, screw-cutting lathes and much else which seems to have been his own invention. It is true that such interests were not exceptional among Leonardo's contemporaries and successors, for from the year 1500 onward a stream of beautifully produced books on gold-refining, mining, machines and all manner of technical procedures attest the importance that his age attached to such pursuits. The glamour of ' secret arts ' or ' natural magic ' clung to these useful arts and it is not in the least surprising that Leonardo should have studied them. What is surprising and attests his genius is the soundness of the designs he made. It is not, of course, to be supposed that Leonardo invented all the machines he drew, but there are recorded in his works designs for machines of which no trace has been found elsewhere, and these we must suppose to be his.

May we, now, perhaps interpret Leonardo's view of the universal man in our own terms ? Truth about natural things is founded in experience, which when treated logically or mathematically, gives rise to the sciences. The sciences tell us the construction and dynamic of things, how they are made and how they work, and this knowledge is the necessary material for every creative work. In addition to what we can rationalise into science, there is much that we can observe and note and store away in a systematic way ; the data of facial expressions, moments of beauty and other complex experiences which find no place among the natural sciences. Such is the equipment of the mind of man, and it is the material on which his creative imagination works. From scientific material alone it may synthesise an invention—engine or appliance : with the more complex data of experience, and the deep emotional directives of the mind, it may rise to the perfect creation of an artistic production, which can be expressed only by techniques laboriously learnt and themselves of the nature of a science. To sum up all, we may think that the principle of the life of Leonardo da Vinci was to observe and systematise in order to create.

Can Leonardo be taken as a model for the scientist of to-day ? I do not think anyone will doubt that a man who has taken hold of the full circle of the sciences and makes them contribute to creative art of the highest order must find in life a far greater measure of significance and —if his temperament allow—of joy, than does the man who penetrates deeply into a narrow field of experience. But is it of any use to model ourselves on Leonardo

if we lack his genius or his love of nature—neither of which is ours to command?

There are minds that work, like a terrier at a rat-hole, utterly devoted to a single object of research, people who are so interested in one thing as to be quite incapable of attending to any other; and I believe this state to result from something at the unconscious level and not from a restriction of the field of view resulting from a narrow or ill-conceived education. There are other minds who find in every science or art, in every avenue of learning, a delicious attraction: who look into all and do not go far with any. The universe is as wonderful in its detail as in its general plan: let us seek to know either and we shall seek a great good. At present the material rewards of life go to the specialists. Society offers what it can give to electrical engineers, organic chemists, entomologists and all such useful human tools: men and women of wider varied interests and achievements have to find therein their own reward.

The structure of present-day society is utterly unlike that of the time of Leonardo. The renascent ideal of humanity was not to be found in the productive society of workers and traders, but was, as it were, a human crown, resting thereon: man as a showpiece, the individual perfectly accomplished and with every perfection. We of the twentieth century belong to a highly organised society conceived on the scientific model, and our ideal is the person who is social, the worker-ant contributing to production or co-operating in the building of science. But we are not yet committed to an education for usefulness alone and so we seek to devise methods by which our young men and women shall have the best of both worlds, and become useful tools of society, yet with a width of understanding and ability which will make them at home in the greater world as well as in the little sphere allowed them in the social machine.

How was Leonardo educated? It seems that at school he learnt no more than reading, writing and simple arithmetic, and that of his own will he practised the graphic art which seems to have come so eaily to him. At the age of 13 or 14 he was put into the studio of Andrea del Verrocchio—goldsmith, sculptor, architect, painter, and musician. He was, in fact, placed in an adult society in the care of a great man, whom he must have enormously admired. I do not believe that any education can compare with apprenticeship to a great man, and that is how I would like to see the very best of our present boys and girls educated. The world is not organised like that to-day, and every teacher has to be his own Verrocchio. Some teachers will smile—but I am serious. A man who knows and can do a wide range of things, and talks about them with enormous enthusiasm, will set his more combustible pupils on fire; a subject, for them, will step out of the textbook and become a part of real life; the boy or girl will want to go ahead with it and once they want to do so, the velocity of their progress is remarkable.

Let the figure of Leonardo da Vinci, then, stand as a monument of what can be achieved by man, but scarcely I think as a model of what any of us can hope to achieve or of the kind of man that society requires to-day. Enough for the present if he reminds us that the specialist is not the only kind of great man, and that there may again be, one day, a world in which the universal man can find his place.

RESEARCH COMMITTEES, 1954–55

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICS AND PHYSICS.

Seismological investigations.—Dr. R. Stoneley, F.R.S. (*Chairman*), Mr. E. Tillotson (*Secretary*), Mr. E. F. Baxter, Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. B. C. Browne, Sir Edward Bullard, F.R.S., Dr. K. F. Chackett, Dr. G. E. R. Deacon, F.R.S., Dr. A. T. J. Dollar, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, C.B.E., F.R.S., Dr. M. N. Hill, Mr. J. S. Hughes, Sir Harold Jeffreys, F.R.S., Mr. E. N. Lawrence, Dr. A. W. Lee, Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S. J., Dr. G. D. Robinson, Mr. H. V. Shaw, Sir Frank Smith, G.C.B., G.B.E., F.R.S.

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Mr. W. H. Wilcockson (*Chairman*), Mr. J. M. Edmonds (*Secretary*), Sir Edward Bailey, M.C., F.R.S., Mr. J. L. Begg, Mr. W. S. Bisat, F.R.S., Prof. P. H. G. Boswell, O.B.E., F.R.S., Prof. A. H. Cox, Dr. E. E. L. Dixon, Prof. W. G. Fearnsides, F.R.S., Prof. T. N. George, Prof. H. L. Hawkins, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, F.R.S., Prof. O. T. Jones, F.R.S. Dr. Murray Macgregor, Mr. T. G. Miller, Prof. L. R. Moore, Dr. F. J. North, Prof. F. W. Shotton, M.B.E., Dr. W. E. Swinton, Dr. F. S. Wallis, Prof. D. M. S. Watson, F.R.S., Prof. T. S. Westoll, Prof. W. F. Whittard, Prof. S. W. Wooldridge. **£30.**

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. H. L. Hawkins, F.R.S. (*Chairman*), Dr. W. S. Pitcher (*Secretary*), Mr. H. Ashley, Mr. G. M. Davies, Dr. N. Holgate, Mr. G. S. Johnstone, Dr. A. G. MacGregor, Dr. F. J. North, Mr. J. Ranson, Mr. G. S. Sweeting, Prof. W. F. Whittard, Dr. Vernon Wilson.

To consider and report on questions affecting the teaching of geology in schools.—Prof. T. N. George (*Chairman*), Dr. Mabel E. Tomlinson (*Secretary*), Prof. J. G. C. Anderson, Miss M. A. Arber, Mr. A. Bray, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Dr. J. F. Kirkaldy, Prof. D. Leitch, Prof. L. R. Moore, Mr. J. Myers, Prof. W. J. Pugh, O.B.E., F.R.S., Dr. K. S. Sandford, Dr. S. H. Straw, Dr. Dighton Thomas, Dr. A. K. Wells, Prof. A. Wood.

SECTIONS D, K.—ZOOLOGY, BOTANY.

Co-ordinating committee for Cytology and Genetics.—Prof. Sir Ronald Fisher, F.R.S. (*Chairman*), Mr. Watkin Williams (*Secretary*), Dr. J. L. Crosby, Prof. C. D. Darlington, F.R.S., Dr. E. B. Ford, F.R.S., Dr. J. Hammond, C.B.E., F.R.S., Prof. S. C. Harland, F.R.S., Dr. J. S. Huxley, F.R.S., Prof. T. J. Jenkin, C.B.E., Prof. K. Mather, F.R.S., Prof. L. S. Penrose, F.R.S., Dr. G. Pontecorvo, Dr. R. R. Race, F.R.S., Prof. P. T. Thomas, Dr. W. B. Turrill, Prof. C. H. Waddington, F.R.S.

SECTION E.—GEOGRAPHY.

To prepare a glossary of geographical terms with agreed definitions in English, including reference to origin and to current use and misuse.—Prof. L. Dudley Stamp, C.B.E. (*Chairman*), Mr. G. R. Crone (*Secretary*), Prof. H. C. Darby, Prof. E. G. East, Mr. E. O. Giffard, M.B.E., Mr. A. F. Martin, Prof. A. A. Miller, Dr. C. J. Robertson, Mr. C. T. Smith, Dr. G. T. Warwick, Prof. S. W. Wooldridge, Mr. R. A. Skelton. **£5.**

SECTION H.—ANTHROPOLOGY.

To co-operate with a committee of the Roya Anthropological Institute—in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Dr. Arthur Court, Prof. H. J. Fleure, F.R.S., Mr. W. H. Hanbury, Dr. J. Wilfred Jackson, Mr. R. U. Sayce.

To assist in the work of compiling an *Inventoria Archaeologica* as part of an international enterprise sponsored by the International Congress of Prehistoric Sciences.—Prof. E. O. James, (*Chairman*), Dr. D. B. Harden (*Secretary*), Prof. C. F. C. Hawkes. **£15.**

To carry out research among the Ainu of Japan, Mrs. Brenda Seligman (*Chairman and Secretary*), Prof. Daryll Forde, Lord Raglan, Mr. Arthur Waley. **£45.**

COAL AND BRITAIN'S FUTURE

At the Annual Meeting in Oxford, Section B (Chemistry), under the Chairmanship of Prof. Sir Cyril Hinshelwood, devoted the morning of Friday, September 3, 1954, to papers on coal and Britain's future. Dr. W. Idris Jones, National Coal Board, dealt with modern coal processing in relation to Britain's coal problem. Dr. F. J. Dent, Gas Council, then read a paper on the gasification of coal and he was followed by Dr. R. Holroyd, Imperial Chemical Industries Ltd., who reviewed coal as a source of chemical raw materials. The discussion which followed the presentation of these three papers was opened by Sir Harold Hartley.

Modern Coal Processing in Relation to Britain's Coal Problem

by
Dr. W. Idris Jones

1. The Coal Problem

Our industrial productivity, incomes and standard of living depend upon the availability and consumption of fuel and energy (1). Coal is our primary source of energy and also an essential factor in the production of steel, textiles, fertilisers, plastics, etc. The possible contributions of hydro energy, wind energy and peat are of relatively minor importance in the U.K. except perhaps in the Scottish Highlands. Atomic energy may become an important contributor of energy, but even so our need for adequate and economic coal production is vitally important. To-day coal for immediate consumption is neither cheap nor plentiful, nationally or internationally. All possible steps are being taken by the National Coal Board to ensure increased and more efficient and economic production of coal, to recruit the requisite manpower for coal winning, planning and production development and to expend the enormous capital necessary in the best manner. Further marked improvements in the efficiency of use of coal in most of our industries and in our homes could achieve a great deal in ensuring the best use of our supplies of coal; it should in fact be possible to increase the overall efficiency of coal utilisation in the U.K. from the current figure of about 35 per cent. to possibly 50 per cent. during the coming decades (1) and thus ensure a higher degree of comfort and a net saving of coal.

The most serious consideration facing us is a relative and absolute decline in the production of coking coals for the coking and gas making industries at a time when both industries are expanding. Another factor of prime importance is that most of the coal mined will be the low rank non-coking or feebly coking types. It is clear, therefore, that we shall have to apply more widely and exactly our knowledge of scientific coal blending as a short term solution and learn how to process low rank coals in such a way that they may be used for the same purposes for which coals of higher rank are now used. Every effort, too, should be made to enhance the potential chemical value of coal; to produce a wider range of chemicals and oils directly from our own indigenous coal, instead of building our chemical foundations on what may prove to be the quicksands of the Middle East. The economic production of these chemicals and oils concurrently with solid smokeless fuels would obviously have a far reaching effect on coal economy and atmospheric pollution, etc.

2. Coal Constitution

To appreciate the potential value of coal as a chemical and source of chemicals it is important to know something about its constitution.

Coals contain carbon, hydrogen, oxygen, nitrogen, sulphur and other constituents in different proportions according to the degree of coalification, etc. They form a series ranging from peat through lignites and bituminous coals to anthracite. The more mature the coal, the greater is its carbon content and carbon/hydrogen ratio and the less its oxygen and hydrogen contents. Its structure is exceedingly complex and extensive efforts have been made for many years by petrologists, paleobotanists, chemists and physicists to unravel its constitution. Early work on oxidation, solvent extraction and thermal decomposition revealed its essentially aromatic structure. Petrology showed that coal consisted of three main rock bands which were called vitrain, durain and fusain; these bands being heterogeneous and comprising several constituent macerals. The principal constituent in bright coal, called vitrinate, is virtually pure coal, but it is itself a complex of chemical structures. The study of the banded constituents of coal has thrown much light on the differences between one type of coal and another but has told us very little about the ultimate constitution of coal.

The work of the physical chemists, notably at the B.C.U.R.A., suggested that the bituminous coals contain a physical unit of coal structure, the micelle. Later the micelle was shown to be an aggregate of molecules held together by strong cohesive forces.

The application of X-rays and infra-red techniques by Riley, Hirsch, Van Krevelen, Franklin and others has further enlarged our knowledge and the latest results during the past twenty years would appear to indicate that throughout the range of vitrains from C = 78 per cent. to C = 94 per cent. a substantial part of the carbon in the coal is in the form of small units of planar, graphitic sheets, increasing in size with the rank of the coal, slowly up to 90 per cent. C and then rapidly. These sheets are preferentially orientated parallel to the bedding plane and are stacked side by side to form a more or less continuous 2-dimensional polymer with pores occurring at distances of 15–20Å from each other. The layers are stacked parallel to each other along a direction normal to the bedding plane. These layers occur in groups and the number of layers per group is characteristic of the rank of the coal and can be as high as 9 or 10 for anthracite and as low as 3 to 5 for a low rank coal. Oxygen, nitrogen, sulphur and hydrogen do not appear to be incorporated in these condensed ring structures to any appreciable extent.

The aromatic, polycylic nucleus in coal, according to present-day investigators is relatively small and contains relatively few hexagonal carbon rings, the number of which increases gradually with an increase in rank. But the major properties of coal appear to be associated with the unorganised constituent, not amenable directly to X-ray revelations. Most of the oxygen and sulphur probably exist as direct cross bridges between the condensed ring structures. Unorganised carbon is conceivably either attached to the ' edge ' valencies as short paraffinic chains or as longer paraffinic bridges. It is probable that not many valencies are satisfied by hydrogen alone and that the unorganised material contains only a small proportion of olefinic or other unsaturated groups. The number of oxygen bridges falls rapidly with rank and at a certain point the anchoring effect of these bridges is reduced to such an extent that the polycyclic units become mobile at relatively low temperatures and the coal melts. A little after this the polycyclic units tend to grow and merge, forming in the case of anthracite rigid mats of organised structure. In the case of coking coals oxygen anchoring declines sufficiently before the development of carbon anchoring to permit these coals to melt before active decomposition sets in and thus exhibit the well-known characteristics of coking coals.

Such, briefly, are the prevailing views concerning coal constitution but much more research work is necessary before the ' open sesame ' stage is reached.

3. Coal Treatment

How can we best undo this complex structure of coal to add to our stock of potential chemicals and fuels? Many methods have been tried in the past, e.g. thermal decomposition, oxidation, hydro-

genation and gasification to yield synthesis gases for conversion into ammonia, methanol, higher alcohols and hydrocarbons of diverse types. The hydrogenation and hydrocarbon synthesis processes have been greatly developed and improved during the past twenty years, but they are not economic under current conditions in Britain. Economic conditions, however, may change in their favour in the future.

Consideration in this paper will be given primarily to coal pyrolysis.

(i) *Pyrolysis of Coal*

When coal is heated various changes take place which are typified by the rank of the coal, the temperature, the rate of heating, the type of apparatus, the thickness of the coal layer and other factors. There appear to be four fairly definite regions of change when coal is heated in the laboratory. Up to 300° C. the coal is virtually unchanged, then from 300° to 550° C. it decomposes to yield a semi coke, volatile matter and gases. Above 550° C. the

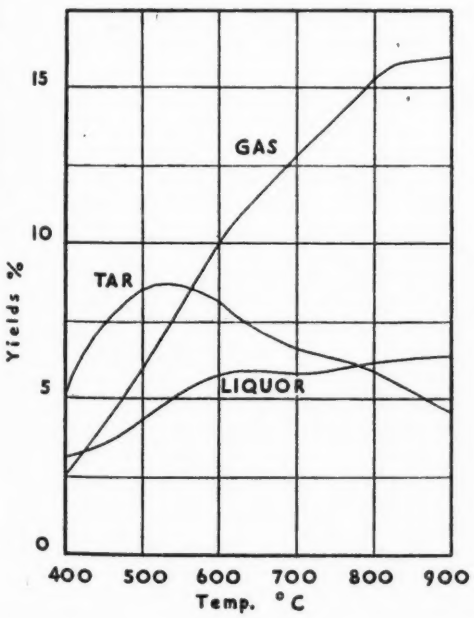


FIG. 1

semi coke is transformed to coke and more gases and above 1000° C. to say 3000° C. there is an increasing order in the lattice structure with approach to graphitisation.

The products of thermal decomposition of coal are coke, aqueous liquor, gas, light oil and tar. Fig. 1 shows for a Yorkshire coal how the yields of these

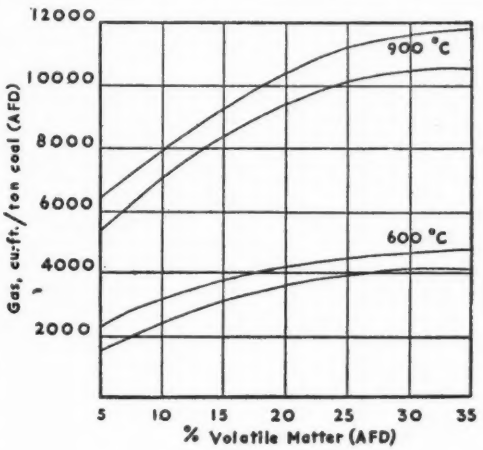


FIG. 2

vary with the temperature. More or less similar variations occur in the case of other coals.

For South Wales coals (2) the yields of gas obtained in laboratory apparatus at two temperatures from coals of various volatile contents are shown in banded form in Fig. 2. The yields of solid residue, tar and gas and the gas composition from South Wales coals are likewise shown in Table I.

The gas produced at 600° C. is rich in hydrocarbons while that formed between 600° and 950° C. is rich in hydrogen. There is also a wide variation in the composition of the tars obtained at different temperatures and/or from coals of different volatile contents. Broadly speaking, the oxygen content and light oil (0°–170° C.) content of the tar diminish and aromatisation increases with increasing temperature of heating. The reactivity of the solid residues also varies widely and ranges from a CAB of about 0·005 cu.ft./min. at 600° C. to about 0·06 cu.ft./min. (at 950° C.) for chars obtained from a coal of 35 per cent. volatile matter. These chars, too, have an ignition temperature in air of less than 400° C. (at 600° C. carbonising temperature) rising to about 450° C. (at 700° C.) and over 500° C. (at 950° C.).

TABLE I

Gray King assays. Yields per ton of coal (dry, ash free)

% Volatile D.A.F.	Coke cwts	Tar Gals.	Gas Cubic Feet	Gas composition by volume	
				Hydrocarbons	H_2
At 600° C					
5	19·6	0	2000	52	31
10	18·8	1·5	2800	54	29
20	17·4	10·5	4000	58	24
25	16·7	16·0	4250	61	20
30	15·9	21·5	4400	64	15
35	15·2	27·5	4500	68	10
At 950° C					
5	18·0	Trace	6000	22·0	68
10	17·4	2·5	8000	22·5	67
20	16·1	6·0	10500	24·5	63
25	15·4	8·0	11000	26·5	60
30	14·8	10·0	11500	28·0	56
35	14·2	11·5	12500	30·0	52
Difference 600–950° C					
20			6500	3·9	87
25			6750	4·8	85
30			7100	5·7	81
35			8000	8·6	76

(ii) *High Temperature Carbonisation*

The flexibility of the high temperature heating process is restricted by the need for a standard type of coal, mainly the strongly coking types which are gradually becoming worked out, and more or less standard temperatures. Furthermore, transfer of heat must take place across a thick bed of coal of relatively poor thermal conductivity, so that heat transfer is poor and extensive cracking of the liquid products also occurs. As a result, the full potentialities of coals for the creation of solid, liquid and gaseous products of variable composition and properties are not realisable. With high temperature carbonisation twenty hours or more of heating time is required and broadly speaking only one type of gas, tar, spirit or coke is produced and the tar is in low yield.

Vertical retort tars are very similar in chemical composition but coke oven tars show a considerable variation in composition due to the variety in the coal blends used and in the conditions of carbonisation. In Table II are set out a few data for vertical retort tars and for two coke oven tars, one produced under mild conditions and the other under more stringent conditions (3).

The figures for the vertical retort tar are the average of those for four tars. The coke oven tar 1 was produced under stringent conditions and the coke oven tar 2 under mild conditions; hence the low pitch and low naphthalene and phenanthrene contents of the latter coke oven tar.

The amounts of the commercially important compounds in the coal tars are

TABLE II

Type of Tar	Vertical Retort	Coke Oven 1	Coke Oven 2	Type of Tar	Vertical Retort	Coke Oven 1	Coke Oven 2
Liquor (wt. % on crude)	3·88	1·55	2·71	Naphthalene	3.09	9·77	7·91
Benzole (50–100° C.)	0·26	0·23	0·44	Me Naphthalene Fraction	3·01	2·38	3·48
Toluole (100–125° C.)	0·28	0·18	0·38	α Me Naphthalene	0·52	0·67	0·86
Xylole (125–150° C.)	0·51	1.19	0.42	β Me Naphthalene	0·67	1·15	1·43
Phenol	0·81	0·61	1·15	Diphenyl Oil Fraction	2·35	1·10	1·68
Cresois	3·78	0·80	2·86	Acenaphthene Oil Fraction	2·78	2·70	3·15
Xylenols	2·98	0·13	1·30	Fluorene Oil Fraction	3·58	1·92	2·96
High Boiling Tar Acids	7·41	0·49	2·09	Anthracene	0·29	1·03	1·13
Total Tar Bases	2·02	1·47	2·60	Phenanthrene	2·68	8·66	3·90
Naphtha Fraction	3·30	0·77	2·66	Carbazole	1·15	1·73	1·55
Paraffins in Naphtha %	−18·0	−3·1	−5·2	Pitch	44·30	64·25	53·80
Indene in Naphtha %	−10·3		−23·2				
Crude Naphthalene Fraction	4·49	10·90	9·0				

apparently little affected by the method of distillation; although the pitch content is generally higher for tars distilled in pot stills than in pipe stills. The effect of distillation on the chemical composition of a tar appears to be confined to some decomposition of the more complex higher boiling components, with accompanying formation of water, paraffins, olefins and some other higher molecular weight products (3)

At present phenol, cresols, xylenols, benzene, toluene, naphthalene and anthracene comprise the bulk of refined coal tar chemicals sold today. The other chemicals in coal tar are not in great demand by the chemical industry and there is much scope for research on their chemical utilisation. We have lagged far behind Germany in this respect.

The total production of coal tar in the U.K. is about 2¾ million tons per annum. Crude benzole production is approximately 106 million gallons per annum (5). These yields are obtained by carbonising over 53 million tons of coal. The appropriate percentages of the tar sold commercially in 1953 are set out in Table III.

The percentage production of refined light oils produced from crude benzole in 1952 are shown in Table IV.

Very few of these commercial products get beyond the refining stage shown in Tables III and IV. Over two-thirds of the total tar and benzole output is considered fit only for use as fuels of various kinds, as road construction materials and as wood preservatives. It is frequently more economic to burn tar in open hearth steel furnaces and glass melting furnaces than to process them for the production of chemicals, solvents, etc.

TABLE III

	% approx.		% approx.
Road Tars	12·90	Pyridine Bases	0·04
Creosote—Pitch Mixture	24·50	Phenol	0·42
Creosote Oil	17·70	Refined Cresylic Acid	1·70
Pitch	23·30	Anthracene (40–50 %)	0·10
White, hot pressed and crude naphthalene	1·30	Miscellaneous	9·04

TABLE IV

	%		%
Motor Benzole . .	47·4	Xylole . .	3·4
Other Benzole . .	19·0	Coal Tar Naphtha .	9·2
Toluole . . .	9·5	Miscellaneous .	11·5

(iii) *Low Temperature Carbonisation*

Low temperature carbonisation is intended primarily for the production of solid smokeless fuel but it gives a greater yield of tar and extends the range of chemicals obtainable from coal by pyrolysis. Many L.T.C. processes have been tried but these necessitate special plant to cope with the swelling and inadequate contracting properties which coals exhibit within the range of up to about 700° C. Only about five or six L.T.C. processes have been operated to any appreciable extent on a commercial scale throughout the whole world. L.T.C. processes again are somewhat restricted in the choice of

TABLE V

	H.T.C.	L.T.C.
Coke, cwts. per ton .	13·5	15
Coke, CAB, cu.ft/min. .	up to 0·08	about 0·04
Tar, gallons per ton .	up to 11·0	up to 27·0
Tar, Type . . .	mainly Aromatic	Paraffinic-Naphthenic —Aromatic.
Crude Spirit, gallons/ton	about 2.0	2·5–3·5
Crude Spirit, type .	as for the tar	as for L.T. Tar
Gas, cu.ft/ton . .	up to 12,500	up to 4500

TABLE VI

Fraction	Light Oil	Middle Oil	Heavy Oil
Crude Tar Acids (per cent.) . .	12	45	35
Hydrocarbons (per cent.) . . .	86	52	65
Hydrocarbons, Saturated (per cent.) .	21·5	12	Complex Mixture including paraffin wax
„ Olefinic (per cent.) .	34·5	14	
„ Aromatic (per cent.) .	30	26	
Crude Bases (per cent.) . . .	2	3	

coal and appreciable cracking of the primary volatile products occurs. Table V shows broadly how the yields, etc., by L.T.C. of coal differ from those obtained by high temperature heating.

The coalite process (4) can be taken as an outstanding example of a current low temperature carbonisation process. Low temperature tar contains large quantities of unsaturated paraffinic and naphthenic compounds and tar acids. Distillation of the L.T. tar gives the following products (Table VI).

The crude gas spirit is composed of (Table VII):

TABLE VII

	%
Saturated Hydrocarbons (Paraffins and Naphthenes)	25
Olefines	50
Benzenoid Aromatics . .	25

The phenolic content of the liquor is composed approximately of 69 per cent. monohydroxy phenols and 31 per cent. dihydroxy phenols. The annual production of the crude liquid products is shown in Table VIII.

TABLE VIII

Crude Tar . .	8,000,000 gals.
Crude Gas Spirit .	1,500,000 „
Liquor (11·5 per cent. phenols) . .	15,000,000 „

The products of this low temperature carbonisation process are used for fuels, phenol-formaldehyde resins, plasticisers, ore flotation agents, wetting agents, disinfectants, etc., while the pitch and creosote are put to conventional use. Other products and pure chemicals are also made and more still could be made from low temperature tar if the market were attractive.

4. THE FUTURE.

There will probably be a substantial increase in the production of high and low temperature tars and spirits during the coming years due to the requirements of increased production of steel and of smokeless fuels.

It has already been emphasised that we shall experience local shortages of the best coking coals during the coming decades and that an increasing percentage of low rank non-caking coals, much of it in the form of fine coal, will be produced. These trends can obviously not be ignored and new techniques will have to be developed to meet these changes. The National Coal Board have this very much in mind and most of the effort at the Board's Central Research Establishment I at Stoke Orchard is directed to this problem.

(A) N.C.B. RESEARCH.

Much of the coal from which the Board must make future supplies of smokeless household fuel, etc., cannot be converted directly into coke, but it can be pretreated and briquetted and the briquettes can then be carbonised. In this way small coal of inferior coking power can be converted into strong, uniform fuels, which are efficient and smokeless. In practice many of the coals which the Board will have to use cannot be carbonised, even in briquetted form, unless they have been pretreated to reduce their swelling and stickiness on heating Furthermore, all coals require first to be cleaned if the final fuel is to contain little mineral matter.

The Board are therefore carrying out systematic research on the four major steps in the manufacture of new fuels and by-products from low rank non-caking or weakly caking coals. These are coal cleaning, initial treatment, briquetting and carbonising. These steps will now be briefly considered.

(i) *Coal Cleaning.*

In cleaning fine coal, froth flotation is the method normally used, and this depends roughly upon the preferential attachment of oil-coated particles to small air bubbles. The function of the frothing reagent used is to oil the coal so that attachment to the air bubbles occurs and to stabilise the resulting froth at a consistency at which it retains the clean coal. The low rank fines are difficult and costly to clean by froth flotation and research,

therefore, is directed to finding improved reagents which will clean these fines effectively and economically. The research also aims at simplifying the plant and in particular dispensing with mechanical elements now used to produce the bubbles and devising simpler and cheaper methods of dewatering the clean fines.

(ii) *Initial Coal Treatment.*

The Board now use a high rank, non-caking South Wales dry steam coal to make the proprietary fuel ' Phurnacite ', now in great demand for use in closed stoves and cookers and these carbonised briquettes are of such excellent quality that they can command the price of the best anthracite. If an attempt is made to substitute for the non-caking high rank coal a caking coal of lower rank, the charge of briquettes forms into a shapeless mass on carbonisation. This phenomenon is obviated when the caking coal is submitted first of all to a mild oxidation with air which reduces the swelling and agglutination of the coal. Oxidation can be achieved in various ways and most attractively by fluidisation. Work at Stoke Orchard is proceeding on these lines and results show that many low rank coals can be treated in this manner and then converted into excellent carbonised briquettes.

Another preliminary treatment of low rank caking coals is being investigated at Stoke Orchard also. This consists of a precarbonisation or devolatilisation at low temperatures in a fluidised bed to give a uniform char. The yield of tar thus obtained is up to about 40 gallons per ton of coal.

This tar decomposes appreciably when distilled at atmospheric pressure. The neutral oil content ranges from 50 to 70 per cent., about 20–30 per cent. of the tar is soluble in caustic soda and sodium bicarbonate and about 1–2 per cent. in sulphuric acid. The neutral oil contains about 5 per cent. of wax, hydrocarbon oils and oxygenated substances. The hydrocarbon oils contain partially hydrogenated naphthalene or anthracene rings, some with long side chains of up to nine carbon atoms.

The gases obtained by low temperature fluidisation are of interest also. Table IX sets out on a nitrogen free basis the composition of the gas (yield 3370 cubic feet per ton) obtained from a Warwickshire coal at 650° C.

Small amounts of *iso*butane, *iso*butene, Butene 1, *Iso*butene 2 and higher unsaturated hydrocarbons were also present as revealed by gas chromatography and infra-red spectroscopy.

The aqueous liquor contained mono- and dihydroxy tar acids, bases, neutral oil and ammonia.

TABLE IX

	CO_2	O_2	CO	H_2	CH_4	C_2H_6	C_3H_8	nC_4H_{10}	C_2H_4	C_3H_6
Per cent.	1·6	0·2	13·6	22·2	48·2	5·7	1·6	0·4	2·0	1·9

Fluidised low temperature heating has many obvious advantages in that it gives a uniform char from a variable coal feed. This char, however, is more difficult to briquette than coal and this problem is receiving close attention.

Another line of pretreatment of the coals under investigation at Stoke Orchard involves the use of chemical modifiers.

(iii) *Briquetting. Untreated Coals.*

Pitch is used as a binder in the ' Phurnacite ' process, but low rank coals require a greater proportion of pitch. If a binder could be found which would obviate the need for a pretreatment stage, a workable and more economic process might be possible. Such a possibility is being looked into at present. It would obviously be of considerable advantage to eliminate the use of binders entirely.

Pretreated Coals.

Coals which have been pretreated in a fluidised bed by oxidation or by

devolatilisation contain a large store of heat which would be lost if they were briquetted at the conventional temperature of about 80° C. To conserve this heat we are endeavouring to briquette the pretreated coals at the temperature at which they leave the fluidised bed.

(iv) *Carbonisation.*

The time of carbonisation in a coke oven is roughly 20 hours and in the Phurnacite process about 44 hours. Further reduction of the coking time would obviously be of considerable value in these days of high capital costs. The use of mobile beds makes this possible.

(v) *Conclusion.*

Considerable effort is being put into this research work at Stoke Orchard, not only with a view to production of tailor made domestic fuels, but also of new types of metallurgical cokes and locomotive fuels. Briefly, the work at Stoke Orchard has shown that it should now be possible, to a marked degree, to control the yield and type of solid, liquid and gaseous products resulting from coal pyrolysis. The reactivity of the chars, as reflected by the CAB test can be made to vary from 0·005 (suitable for CS_2 production for example) to 0·08 cubic feet/min. Tar yields of from 5 to 50 gallons per ton of coal and of different compositions can be obtained. The gases obtainable range from hydrocarbon rich gases to hydrogen rich gases.

A possible application of fluidised devolatilisation is in the pretreatment of pulverised coal for boiler plants as is being done with local lignites in Texas, the char being fed to the boilers and the tar, gas and liquor treated conventionally.

It remains to be seen how many of the unit or integrated processes now under investigation will be feasible economically on a technical scale.

(B) *Gasification and Inorganic By-products.*

Significant progress in the processing of coal abroad has been made by means of oxygen gasification. The progress in this work was reviewed at an international conference at Liège in May, 1954 (6).

One particularly interesting line of development (6) is to combine coal gasification with a metallurgical process. The Thyssen Company of Duisberg mixes iron ore with weakly caking gas coal, carbonises the mixture and then feeds the resulting iron-coke with the coarser size iron ore into a low shaft blast furnace. This composite process completely gasifies the coal and yields pig iron as a by-product. The gas produced may be used for town purposes or upgraded for synthesis.

Another process under investigation in Holland and Germany involves the interaction of O_2 in wet bottom slagging producers or cupolas with coal and lime to yield calcium carbide and synthesis gas.

Ferro alloys might also be produced by these techniques.

(C) *Carbon Ceramics.*

The production of the carbon known as Delanium (7) is a triumph for British research into coal processing. By this process a whole series of grades of carbon with properties which may be varied according to the service required can be produced directly from coal. This research was initiated by the B.C.U.R.A. and progressed and developed by Powell Duffryn Research Laboratories Ltd. and Powell Duffryn Carbon Products Ltd. at Hayes. The principle of manufacture is based on the observation that over a carefully controlled range of temperatures a plastic carbonaceous mass of coal will decompose and simultaneously harden and shrink. A typical method of manufacture (8) consists in reducing a low volatile coking coal to an average particle size of 20 microns, adding a swelling inhibitor such as powdered graphite, compressing and carbonising the artefact to 1000° C. The carbon obtained may be graphitised in an electric furnace.

Delanium carbon and graphites find a use in heat exchangers, furnace linings, absorption towers, turbine gland and pump sealing rings and as tiles, tubes, electrodes, generator brushes and in the manufacture of corrosion resistant equipment.

(D) *Solvent Extraction.*

The three chief obstacles in the way of chemical investigation of coal are its solid condition, its heterogeneity and the difficulty of obtaining sufficiently unchanged and yet recognisable fragments when using the classical methods of

organic chemistry. In order to overcome the first and second of these, it is necessary to get the coal into a liquid form and then fractionate the liquid. Work by the B.C.U.R.A. (8) has shown that up to 90 per cent. of certain bright coals can be dissolved directly by certain organic solvents, decomposition being minimised by the use of amine solvents at temperatures up to 200° C.

For commercial purposes high boiling tar fractions at 350°–400° C. might prove satisfactory and serve as a basis for the production of new coal products by fractionation and other treatments of the extracts.

REFERENCES

(1) 'Energy for Britain—the Decades ahead.' W. Idris Jones. Presidential Address to the Institute of Fuel, 1954.
(2) 'Research in the Coal Mining Industry,' 19th William Menelaus Lecture. W. Idris Jones. *Proc. S. Wales, Institute of Engineers*, **68.** No. 1 6–31, 1953.
(3) *Composition of Coal Tars.* McNeil and Vaughan. Inst. Gas Eng. 19th Autumn Research Meeting, November 24–25, 1954.
(4) *Coke and Gas.* **14.** 355–362 ; October 1952 and 40–407, November 1952.
(5) *Statistical Digest.* Ministry of Fuel and Power, 1953.
(6) *Gas World.* **139.** 1376–1379, May 22, 1954.
(7) *Times Review of Industry.* April 1950, p. 25.
(8) *Research.* **6.** 29–35, January 1953.
(9) *The Times Science Review.* No. 4, Summer 1952.

TOWN GAS PRODUCTION BY GASIFICATION PROCESSES

by

Dr. F. J. Dent

SMOKELESS, clean, convenient and amenable to precise control, town gas has most of the properties of an ideal fuel. Its use has increased steadily until now the heat units distributed as gas are equal to 6 per cent. of those in the total coal mined, with an estimated annual saving of over 20 million tons of coal. At a time when it has never been more important to economise in coal, when everyone is acutely conscious of the evils of air pollution, and when the refinement of industrial processes needs corresponding refinement in methods of heating, it is of prime importance to know whether much more coal could not be gasified so that the use of gas could be extended to general heating purposes.

On the grounds of cost alone, this would require the coal to be converted at high thermal efficiency in a relatively cheap plant and, clearly, there must be little restriction as regards the type of coal. There must also be flexibility in operation since the more extensive is the use of gas, the more desirable will it be to suit production to variations in demand.

In the light of recent technical advances it seems that all these requirements will soon be attainable but only by having some alternative to carbonisation, the principal process now used for gas manufacture. The carbonisation of coal, operated since gas was first introduced for lighting, is now highly developed, but it has limitations which would probably militate against a further major increase in gas production. To some extent these are due to the cost and inflexibility of the plant but, more particularly, they are concerned with coal supplies.

When coal is carbonised, gas is not the only product and its yield is relatively low because of this. It is restricted to that driven off as 'volatile matter' on heating the coal, much of which remains as a solid coke residue.

Yields on a Thermal Basis

Coal				
Gas	25		,,	,,
Tar	5		,,	,,
Coke	50		,,	,,
Losses	20		,,	,,
	—	100	,,	,,

A correspondingly large amount of coal is needed per unit of gas and, perhaps of more importance, the coal must be of a special kind. It must be rich in volatile matter to give sufficient gas, be reasonably low in ash, and fusible enough to produce a good coke. But, while all coal is scarce, it is this caking type which is becoming the most difficult to obtain. The plans of the Coal Board are to mine a greater proportion of weakly caking coal and more mechanisation is expected to increase the production of high ash smalls. These are likely to be the coals most readily available for gas manufacture and, except in limited

quantities, they are unsuitable for carbonisation.

It is for these reasons that a large increase in the production of gas from coal seems to require some other process. We now believe that one with the desired features will soon be obtainable, and it will gasify the coal completely as a result of the initial thermal decomposition being followed by the reaction of residual carbon with steam,

$$C + H_2O \longrightarrow CO + H_2.$$

It is as well, however, to appreciate what such a process involves since, clearly, its chemistry is quite different from that of carbonisation. A gasification system absorbs the elements of water and does not reject carbon as coke but yet, for a time at least, the gas finally obtained must be interchangeable with that from existing plants. The gas need not have the same empirical composition as coal gas but, for satisfactory behaviour in appliances, it must be of similar calorific value and density. It must have a calorific value of 450–500 B.Th.U. per cu. ft. and a density of about 0·5 (air = 1).

The composition of coal is then sufficient to show that, in meeting this requirement, besides providing for the straightforward reaction with steam, a suitable gasification process must :—

(a) increase the production of methane above that normally obtained by thermal decomposition so as to give the required calorific value in the greater volume of gas obtained per ton of coal, and

(b) avoid too high a density in the gas by rejecting both carbon and oxygen. This can be done by converting carbon monoxide to hydrogen by means of additional steam and then removing carbon dioxide.

$$CO + H_2O \longrightarrow H_2 + CO_2$$

Until a few years before the war, these operations always appeared formidable. Indeed, it can be argued that it has been because of them that carbonisation has persisted as the basic method of gas manufacture. In 1935, however, the Lurgi process was introduced in Germany and showed that a considerable simplification could be obtained by conducting the whole of the gasification under a pressure of several atmospheres.

The Lurgi process uses a generator, similar in design to a normal mechanical producer, except that it allows gasification to be carried out in steam at 20–30 atmospheres. Oxygen is added to the steam to liberate the heat required by the gasification reaction, and the output is readily variable through the rate at which this oxygen and steam mixture is supplied. The unique feature is, however, the use of pressure which is found to have several advantages :—

1. It reduces gas velocities through the fuel bed so that small fuel can be gasified at high output with little loss of dust from the generator. The fuel can be down to $\frac{1}{8}$ in. in size, and can contain as much as 30 per cent. of ash.
2. Under pressure, methane is stable at the temperature of the fuel bed and is formed during the gasification itself. The gas produced contains considerably more methane than can arise from 'volatile matter' and has a calorific value of 400–450 instead of about 330 B.Th.U. per cu. ft.
3. Steam, used in excess to prevent clinker formation, reacts in the fuel bed with carbon monoxide and the density of the final gas is quite normal.
4. Pressure then facilitates the removal of the carbon dioxide by washing the gas with water or, preferably, with organic solvents, which also eliminate gum formers and sulphur compounds, to give a higher standard of purity than has hitherto been attained in town gas.

This process was initially developed for the gasification of lignite. Large installations have operated on the Continent and more are being erected. It clearly has most of the desired features. In fact, technically, only two further developments were required before its use in this country and these were, first, a modification of the generator so that it would gasify bituminous coals, which differ from lignite in that they tend to agglomerate when heated under pressure and, secondly, an

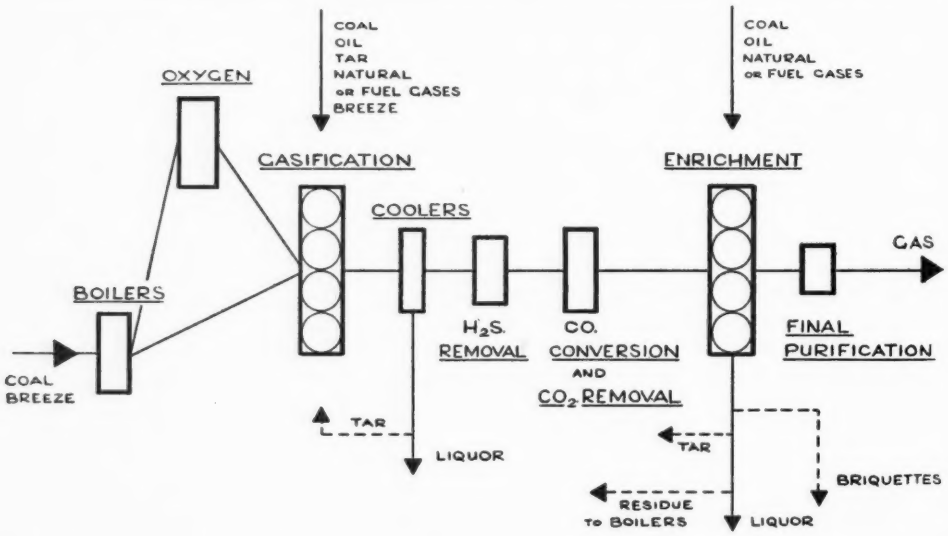
increase in the calorific value of the gas which, at 400–450 B.Th.U. per cu. ft., was still rather low.

Modifications to the design of the generator have been made in Germany and tests have shown that it is now capable of dealing with a wide range of British weakly caking coals. The increase in calorific value has also been achieved, work in England having concentrated on this aspect. It has been found that the formation of additional methane under pressure is the result of hydrogen from steam reacting mainly to be regarded as a method for widening the range of the coals used for gas making and it is important on that account. Is there, however, opportunity for the further development of what is still a relatively new process? Evidence suggests that there is.

Because of the nature of the process, development will not be confined to any single feature. As already indicated, the conversion of coal to gas involves a number of steps and minimum costs will only be achieved if each is carried out at maximum

FIG. I.

LAY-OUT OF A COMPREHENSIVE SCHEME OF PRESSURE GASIFICATION.



with the coal and that the extent of this hydrogenation reaction can be increased if the best use is made of the pressure available.

The process can therefore be regarded as satisfactory in so far as it will produce a suitable gas from low grade coals and capital charges are only about half of those of carbonisation. Are its overall economics also satisfactory? As far as can be ascertained without full scale trial in this country, the cost of gas production would, in many localities, be lower than by carbonisation but not low enough for the expansion of gas production as contemplated in this paper. In its present form, therefore, the Lurgi process is efficiency. If gas is to be competitive for general heating, production processes must leave no margin of avoidable losses, and take full advantage of there being no restriction by natural laws such as those which limit the efficiency of utilising coal for power generation. Then it is realised that while a first attraction of the Lurgi process was that the gasification in steam, the conversion of carbon monoxide, and the formation of methane occurred in the one fuel bed, the individual performances do not compare favourably with those attained under other conditions and they are all capable of improvement. For example :—

1. Of the process steam supplied, less

than 10 per cent. is decomposed in the gasification of carbon and not more than 30 per cent. in the conversion of carbon monoxide, whereas, in some gasification processes, 75 per cent. of the steam reacts with carbon, while in the commercial operation of carbon monoxide conversion, up to 60 per cent. of steam is decomposed.

2. The same commercial processes will reduce the concentration of carbon monoxide to 2–3 per cent. as compared with 20 per cent. in the Lurgi process, with a corresponding increase in the partial pressure of hydrogen. If such higher partial pressures were obtained in a gasification process there would be much greater scope for the hydrogenation reaction. This is of the greatest importance since, under favourable circumstances, hydrogenation can double the gas output without using any more steam or oxygen. The most costly step in gasification is the production of a hydrogen-rich gas under pressure. Having obtained it, cheap town gas depends upon exploiting hydrogenation as far as possible.
3. While the removal of carbon dioxide has been cheapened by the use of organic solvents in place of water, the fact remains that a gas separation theoretically capable of liberating energy, still absorbs heat and power equivalent to 7·5 per cent. of the total heat supplied. There is plainly room for further economy.

Consideration indicates that the maximum performance in the various steps will only be obtained by having separate control over each and this is quite logical. Efficient reaction with steam requires a high temperature, efficient conversion of carbon monoxide a low one, while the production of methane is favoured by an intermediate range with the partial pressure of hydrogen as high as possible. Optimum conditions for each cannot be obtained in the same fuel bed and all experimental work indicates that individual control will improve both efficiency and flexibility.

In more detail, developments being considered are :—

1. Increasing steam decomposition by operating with higher temperatures in the fuel bed, withdrawing the ash as a slag ; the thermal efficiency of gasification will then approach 80 per cent.
2. Obtaining the maximum efficiency in carbon monoxide conversion by using catalysts in a separate stage incorporating the removal of carbon dioxide.
3. Enriching the gas by means of the hydrogenation reaction, again in a separate stage and after steam, carbon monoxide and carbon dioxide have been removed so that the pressure of the remaining hydrogen is as high as possible.

The plant lay-out will then be broadly as shown in the diagram and will consist of :—

Boiler plant,
Oxygen plant,
Gasification stage,
Condensation with rejection of tar and liquor,
H_2S removal,
CO conversion and CO_2 removal,
Enrichment stage,
Final purification.

This system underlies a programme of research being carried out by the Gas Council. It will be appreciated and it can be emphasised that it is more comprehensive than the present Lurgi process and represents rather the full development of pressure gasification for town gas production. Thus, while the gasification stage may have standard or slagging generators, it may also include units for the fluidised or suspended gasification of powdered coal, breeze, tar and petroleum oils, as well as for the reforming of natural and other fuel gases, and similarly in the enrichment stage. In fact, once a works has been laid out for pressure gasification with oxygen, steam supplies, etc., it would be relatively simple to effect modifications in the gasification and enrichment stages to suit any raw material.

Further, whatever raw material were used, the composition of the final gas could

correspond with any calorific value up to 1000 B.Th.U. per cu. ft., a fundamental feature characteristic of pressure operation, as reactions can be governed by equilibria at every stage, different, for example, from a process of thermal decomposition such as carbonisation, in which so much depends upon the nature of the coal. As in Lurgi gas, there would be only four simple gas constituents, viz., carbon monoxide, hydrogen, methane and nitrogen, but now with the proportions of each under full control, the methane to determine calorific value, the ratio of hydrogen to carbon monoxide to suit output, and the nitrogen to control gas density. Eventually, there might be no restriction to the present properties of coal gas, and then gas composition could be chosen to suit distribution and use.

When it is coal that is being hydrogenated in the enriching stage of the system outlined above, the solid residue might be transferred to the gasification stage for the production of hydrogen-rich gas. It should be noticed, however, that during hydrogenation, most of the sulphur in the coal is removed and recovered as hydrogen sulphide and the residue contains only 0·1 to 0·2 per cent. of this constituent. Being also readily combustible, the residue might therefore find other applications, e.g. as the basis of a solid smokeless domestic fuel or as a fuel for power stations, when the flue gases would no longer call for treatment.

The significance of pressure gasification is due to its adaptability in so many directions which embrace most if not all the production features which have been sought at various times. With this unique characteristic it goes far beyond the immediate requirement for an alternative to carbonisation, and offers a unified system of gas making capable of suiting any foreseeable circumstances. If the gas industry is to become the purveyor of refined heat for general purposes, a greater role than it has played in the past, then it needs some such system to facilitate the assumption of its wider function, opportunity for which has been increased by the broader groupings set up on nationalisation. Particular mention might be made of the high rates of gasification obtained under pressure which allow high outputs from individual gas-making units without an increase of the labour force, while, more obviously, the distribution of gas over longer distances at the high pressures would allow manufacture to be concentrated in large works, sited with respect to supplies and raw materials, whatever they might be.

Finally, the overall cost of gas production on the basis of heat units should be little more than twice the cost of pithead coal. Taking into account its greater efficiency in use, its high purity, and its convenience, this should make gas competitive with solid fuel for a wide range of heating purposes and it is therefore believed that gas will satisfy a greater proportion of the smokeless fuel demand than is usually contemplated. Then, with production at an overall thermal efficiency of approximately 80 per cent., there will be a considerable saving in coal.

The technical developments which have been envisaged are not regarded as aims for the distant future. Vigorous investigations of gasification processes are being carried out in various parts of the world and much is now known of the use of oxygen, slagging operation, powder techniques, hydrogenation, oil gasification and so on. What remains to be done consists mainly of selecting those elements which lead to the highest performance and integrating them into the pressure system. Without minimising the effort required for this final stage it is nevertheless believed that, with the Lurgi process as a basis on which to build, a flexible system of gas production could be made available in a few years.

Coal as a Source of Organic Chemical Raw Materials

by

Dr. R. Holroyd

General World Trends in Provision of Basic Organic Chemicals

The story of the rapid development of modern organic chemical industry is well known as far as it concerns new discoveries and products such as polythene, nylon and penicillin. Much less, however, has been heard of the equally interesting and

vitally important part of the story which deals with provision of raw materials in adequate quantities and at low enough cost to make these new developments possible.

One reason for this is that, in the early days of the industry, two sources, namely vegetable products and coal, were easily able to provide these raw materials, largely as by-products to other manufactures. Development of the aliphatic field was for a long time satisfactorily based on alcohol produced by fermentation mainly of molasses, a by-product of sugar refining, on methanol, acetone, etc., by-products of wood distillation and on glycerol, a by-product of soap manufacture. Similarly, development of the state of affairs was preceded by the appearance in petroleum oil and natural gas of two additional sources of organic raw materials.

The contribution of petroleum was originally and is still largely made via by-products made in the course of breaking down heavier oils to petrol. Its most important and widespread contribution has been in the aliphatic field in which products based on the olefinic gases ethylene, propylene and butylene have not only supplemented the existing supply of basic chemicals from vegetable products, but have already gone some way to replace this latter source because of lower costs.

Chemicals from oil are not, however, limited to the aliphatic field. Appropriate

TABLE I

Examples of Recent Contributions of Petroleum to Aliphatic Chemicals in the U.S.

Product	Quantity Units	Production from Petroleum						Production from Other Sources					
		1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952
Ethylene	Million lb.	342	383	1129	1822	1799	1809	—	—	—	—	—	—
Propylene	Million lb.	—	—	287	694	1148	996	—	—	—	—	—	—
Ethyl alcohol	Million U.S. gals.	70·2	73·7	94·9	104·0	113·5	125·9	60·8	101·1	89·8	60·9	120·6	120·2
Acetone	Million lb.	357	444	388	459	538	404	40	27	25	23	22	36
Glycerol (estimated)	Million lb.	—	15	36	36	40	50	208	181	158	190	171	138

synthetic dyestuffs industry and of the aromatic field of chemistry generally was dependent on the by-products unavoidably produced in the production of coke and town's gas by coal carbonisation. These by-product raw materials were supplemented in the aliphatic field by methanol and later higher alcohols synthesised from coke water gas and by acetylene made via calcium carbide from coke. Since coke is the major product of coal carbonisation it is justifiable to regard these two routes as using coal itself as the primary raw material.

It is within the last decade that the extent and range of world demand for basic organic chemicals has increased so enormously that the by-product vegetable and coal sources of supply have become altogether inadequate. Fortunately this oil fractions can be subjected to combined dehydrogenation, isomerisation and cyclisation to give products containing 50 per cent. or more of aromatic hydrocarbons and this operation is now carried out on a large scale in many refineries in order to improve the knock rating of petrol products. The so-called aromatised products can relatively easily be worked up to give benzene, toluene and xylene, although the process of extraction and purification is rather more involved and costly than is the case with crude benzoles from coal carbonisation. In this aromatic field, oil has supplemented supply but has not replaced and is not likely to replace whatever by-product production is available from coal.

When available in adequate quantities and in the right place there are obvious

TABLE II

Examples of Recent Contributions of Petroleum to Aromatic Chemicals in the U.S.

Product	Quantity Units	Production from Petroleum						Production from Other Sources					
		1947	1948	1949	1950	1951	1952	1947	1948	1949	1950	1951	1952
Benzene	Million U.S. gals.	—	—	—	10	33	36	168	174	133	176	233	216
Toluene	Million U.S. gals.	27	50	48	45	56	64	33	34	34	38	46	41
Xylenes	Million U.S. gals.	33	53	49	62	64	62	8	8	8	9	11	10

advantages in using oil refinery by-products or intermediates for production of basic organic chemicals. It is, however, an important feature of the oil source that, when necessary, crude oil or preferably selected petroleum fractions can economically be subjected to severe cracking or other treatment with the primary object of producing chemicals. These are obtainable from oil in sufficient yield for the accompanying petrol and fuel oil to be regarded as by-products of the process.

Natural gas has come into the chemical picture mainly as a result of the development of the methane/steam and later the partial oxidation process for conversion of hydrocarbons into the carbon monoxide/hydrogen mixtures usually known as 'Synthesis gas' and used extensively for manufacture of methanol and ammonia. In the United States and other parts of the world where natural gas is readily available it has replaced, or is in process of replacing, coke as a raw material for synthesis gas; not because of a shortage of coke but on grounds of lower costs. Thus, whereas all United States methanol manufacture prior to 1940 was based on coke, more than 80 per cent. of present production comes from natural gas. Similarly 80 per cent. of America's ammonia production before the war employed coke water gas. Since the war U.S. ammonia capacity has increased more than 2½ times and over 80 per cent. of the increase is based on natural gas. Sixteen new ammonia plants are at the moment under construction and none of these will use coke. One of them, however, will make its synthesis gas by partial oxidation of petroleum fuel oil rather than natural gas. This development is most important since it could provide most of the economic advantages previously limited to natural or refinery gas to operators unable to site their plants near to natural gas fields or oil refineries.

The purpose of my paper this morning is to examine, bearing in mind these general world trends, the present and probable future contribution of coal as a source of organic chemical raw materials in this country. It will be convenient to consider such contribution under two headings representing the most important routes to chemicals from coal, namely :—

1. Through aromatic materials obtained by the breakdown of coal by carbonisation or destructive hydrogenation, and
2. Through synthesis gas.

THE U.K. CONTRIBUTION OF COAL AS A SOURCE OF AROMATIC CHEMICALS

Present Position

Because this country has possessed no natural gas supply nor, until recently, any appreciable production of by-product oil refinery gases, town's gas manufacture is one of its major industries. At present it accounts for the carbonisation of some 27 million tons of coal per annum, rather more than is carbonised in coke ovens for production of metallurgical coke. As a result the per capita quantity of coal carbonised in the U.K. is 1·85 times the United States figure and, consequently, we are better off than the American by much the same factor in respect of availability of coal benzole and coal tar chemicals.

In these circumstances it has been necessary in only one instance so far to call on petroleum to supplement supplies

of aromatic materials. This exception is in respect of xylenes now required in considerably increased amounts for production of terephthalic acid for Terylene. Production of ' natural phenol ' from coal tar is also no longer adequate to meet demand and has to be supplemented by synthetic routes. Since, however, these are all based on benzene, all this country's phenol production is still coal based.

Table III shows the present demand for some of the more important aromatic chemicals, expressed as an approximate percentage of the availability from present supplies of crude benzole and coal tar. The figures assume the general and efficient use of the best methods of extraction and purification so far established in large-scale practice.

TABLE III

Product	Demand as % potential availability
Benzene . . .	35
Toluene . . .	70
Xylene . . .	120
Phenol . . .	200
Cresylic acid . .	80
Naphthalene . .	60

The favourable benzene position is particularly noteworthy; while other countries are resorting to petroleum sources we are still providing over 50 million gallons per annum of benzole for inclusion in petrol.

Future Position

How long will this adequacy of supply from existing coal sources last? Table IV shows the increase in U.K. demand since 1947 for a number of aromatic materials. Demand in 1947 is expressed in each case as 100.

The average increase in demand for benzene over this period has been of the order of 17 per cent. per annum, that of toluene 8 per cent., of naphthalene 5 per cent. and of cresylic acid about 3 per cent. Corresponding American figures are approximately 15 per cent., 8 per cent., 8 per cent. and 10 per cent. for benzene, phenol, cresylic acid and naphthalene respectively. Considering that organic chemical development as yet lags somewhat behind that in the U.S.A., it would not seem unreasonable to assume that for some years to come, the U.K. demand for benzene, the most versatile of the aromatic raw materials, will increase by about 15 per cent. per annum. 5 to 8 per cent. per annum would appear to be a likely rate of increase in demand for the other basic chemicals in this field.

In comparison the rate of increase in production of crude benzole and of coal tar in recent years averages approximately 3 per cent. per annum. If this continues we might expect therefore to be in need of supplementary supplies of benzene in 10 or 12 years' time and of the other aromatic chemicals about 8 years hence.

This probably puts the position in the most favourable light. It seems unlikely that anything will replace the blast furnace in the foreseeable future and carbonisation of coal to give metallurgical coke is likely to increase, say, at about 5 per cent. per annum. On the other hand, as we have heard from Dr. Dent, every effort is being made by the gas industry to avoid coal carbonisation in town's gas manufacture. Success in this

TABLE IV

Product	Demand						
	1947	1948	1949	1950	1951	1952	1953
Benzene . . .	100	114	105	147	201	196	269
Toluene . . .	100	108	111	122	138	124	160
Naphthalene . .	100	123	117	124	128	130	—
Cresylic acid . .	100	113	80	114	133	118	116

direction would mean at least no further expansion of chemical supplies from gas undertakings and in time would lead to a decline in availability from this source as coal carbonisation plants were replaced by direct gasification equipment. Furthermore, estimates of future aromatic chemicals requirements are based mainly on probable extensions of known uses. One or two major new discoveries creating a demand for, say, 10,000 tons per annum of an aromatic raw material could easily advance the date of a short fall in supply by two or three years.

Possibilities of Increased Supply from Coal

If conventional methods of supply of aromatic products from coal are likely to be inadequate in around ten years' time there is not too much time in which to seek improved methods, or to arrange that supplementary supplies will be available from petroleum sources.

One obvious step is to ensure that the best possible use can be made of available coal carbonisation by-products, and it is reassuring to note that bodies such as the Coal Tar Research Association and B.C.U.R.A. are actively engaged in research on this problem. There are two main lines of approach. The first is to improve methods of extraction from tar of materials already in demand by the chemical industry and which are present in tar as such. There is considerable scope for example for improvement in the efficiency of extraction of cresylic acid, naphthalene and anthracene. The second line involves conversion of some of the more complex tar compounds into simpler substances usable as chemical raw materials. For example xylenols and higher phenols generally can be dealkylated to produce phenol and cresylic acid. Similarly complex hydrocarbons can be broken down to produce benzene, toluene and xylene.

About a year ago I gave details in the second B.C.U.R.A. Coal Science Lecture of a treatment of crude vertical retort tar which gave weight yields of 6 per cent. benzene, 6 per cent. toluene and 4·5 per cent. naphthalene, together with other usable products. Another example is the possible oxidation of methyl naphthalenes or of phenanthrene to phthalic anhydride in order to supplement supplies of naphthalene normally used for this purpose.

Major extension of low temperature coal carbonisation to give smokeless fuels would automatically increase availability of aromatic chemicals, particularly tar acids. The yield of recoverable chemicals is, however, too low for their value to cover the cost of carbonisation and other processing and the future of this industry is entirely dependent on the premium price which can be charged for a smokeless solid fuel. This failure of low temperature carbonisation to answer the problem illustrates the chief disadvantage of coal as a chemical producer. Although its pyrolysis products are highly desirable because of their aromatic constitution derived from that of the original coal, their yield is too small for the operation to be economic unless a major product such as coke or gas can carry the processing cost.

It is because destructive hydrogenation processes can give chemical products in considerably greater yield than simple carbonisation that they offer intriguing possibilities. The Carbide and Carbon Chemicals Corporation have already in operation a large pilot plant operating a mild hydrogenation process. They claim yields of phenol, cresylic acid and naphthalene which are respectively 60–80 times, 100–200 times and 5–8 times those obtainable by simple carbonisation. This order of yields has been confirmed by other workers. Economically the difficulty of the process is the requirement of 3 to 4 parts by weight of hydrogen for each 100 parts of coal treated. It is, however, far too early to judge the economics of this method which is well worth considerable further research.

The U.K. Position of Coal as a Producer of Chemicals

Via Synthesis Gas

Here again, the absence of natural gas has been the major factor enabling coal to hold its position. Apart from a small production at Billingham and Heysham from refinery gases, synthesis gas manufacture has continued to be based on the conventional coke gasification method.

This, however, cannot continue. The special high ash melting coking coals required for this process are becoming increasingly scarce and the method is very expensive in both capital and operating costs.

Recently considerable advances have been made, chiefly in America and Germany, in the development of processes for the direct gasification of a wide range of more readily available coals. These processes in the main are truly continuous, employ oxygen instead of air and operate under pressure and at temperatures high enough to allow ash compounds to be removed from the generator as a molten slag. The output of a unit generator is extremely high compared with conventional water gas plant and capital costs are consequently lower. In the next year or two, one or two of these processes should be sufficiently developed for them to be put into practical full scale use.

Technically this represents a great advance but it must be borne in mind that, simultaneously, processes with the same or even greater advantages have been developed for the gasification of fuel oil. Compared with oil, coal has the fundamental disadvantage of being a friable solid relatively expensive to handle. It also contains a fairly high proportion of ash compounds which have to be purged from any processing system either as a non-agglomerated solid or as a molten mass and this limits the temperature conditions which may be used in different parts of the apparatus.

No matter what technical success is achieved in direct coal gasification, this process will always be more expensive than a corresponding oil process in both capital and in operating (excluding raw material) costs. With a free choice of raw materials coal will be used only if it is relatively cheap enough for this to compensate for its physical disadvantages.

Table V compares the price of coal in the U.K. in recent years with that of crude oil at Texas Gulf port and also as delivered in the U.K. Clearly unless the relatively steep upward trend in coal prices is arrested there will be considerable incentive to adopt an oil route to synthesis gas.

TABLE V

Comparison of Price of Coal and Crude Oil

Year	Average Proceeds for sale of Coal in U.K.	Average value of U.K. Crude Oil imports	Crude Oil East Texas Gulf price	Ocean freights U.S. Gulf to U.K.
1948	100	100	100	—
1949	101	99	100	100
1950	101	120	100	130
1951	108	143	100	210
1952	121	155	100	230
1953	130	126	106	120
1954 approx.	140	127	109	115

Fischer Tropsch Type Processes

Discussion of the possible contribution of coal to chemicals production via synthesis gas would not be complete without mention of Fischer Tropsch Type Processes. If and when it becomes necessary as a defence measure, or commercially attractive to make any substantial proportion of this country's petrol and diesel oil requirements from coal in this way, there would automatically be made available very large quantities of aliphatic chemical raw materials. Coal would then be brought in as a source of the type of

chemical, e.g. alcohols, ketones, etc., originally derived from vegetable products latterly from olefines from petroleum and pyrolysis.

It is certainly desirable to have full knowledge of the potentialities and costs of this process and this can be obtained only through large scale experience. Nevertheless, the relative price trends of U.K. coals and world oil shown in Table V, coupled with the shortage of coal for existing purposes in this country, the large world reserves of petroleum and the even larger reserves of shales and tar sands, to my mind make large scale use of the process in this country an unattractive proposition. Development of the process would appear to be best carried out in countries such as South Africa where freights make petroleum products extremely expensive and where coal is still plentiful and cheap.

Discussion

Sir Harold Hartley, in opening the discussion, said that the future of Britain, so far as coal is concerned, depended on three factors : the winning of more coal at an economic cost; the burning of raw coal more efficiently, and the scientific processing of coal to yield higher grade products. The papers and discussion this morning dealt with the third of these factors. While it was important to use coal, our main indigenous raw material, to the best advantage, the economy of each process depended on the gain in value of the products being greater than the cost of processing. For instance, it might be possible to process much of the coal burnt in power stations and extract the liquid products by the low temperature fluidized bed technique described by Dr. Idris Jones, provided that the added value of the products was greater than the cost of processing. The char would replace the pulverised coal now burnt under the boilers. The present high cost of coal in the U.K. made such processes as the Fischer Tropsch synthesis of oil by conventional methods uneconomical. He stressed the importance of making the best use of the products of processing. For instance, the rich gas from coke ovens should not be wasted by being used to heat the coke ovens, as this could be done by cheaper producer gas made by modern methods direct from coal without involving the use of coke.

The three papers they had heard gave a valuable summary of the present possibilities of the more scientific processing of coal and should be published with a summary of the discussion.

Dr. J. Burns (Chief Engineer of the North Thames Gas Board) emphasised the importance of papers of the kind they had just heard to the fuel-usage industries of the country. He wished to deal particularly with the position of the gas industry in the country's present phase of inadequate coal supplies. The industry had been badly hit through the deterioration in quality and the inadequacy of quantity of its traditional supplies of gas making coal and was turning more and more to oil for its raw material. Much work had been done on the production of towns' gas from various grades of oil. Oil companies had been of great assistance in helping the industry to find the most suitable supplies of raw materials, and the gas industry was well set to use oil in very large quantity.

Processes for the gasification of non-coking coal such as described by Dr. Dent were of much value and technically efficient. Both the Lurgi process and the Gas Integrale process for the gasification of non-coking coal were well tried on the Continent, and a large plant incorporating the Gas Integrale principle was in the course of erection in London. Sufficient information was now available to predetermine the production efficiency of the gasification of non-coking coal, and it was clear that in broad and general principle there was likely to be little difference in the costs of production of gas from coking coal by traditional methods, by the gasification of non-coking coal and by the gasification of oil under existing conditions of costs and raw material prices. The future of the industry, therefore, was likely to depend on the forward availability and price of these three raw materials.

Non-coking coal was more readily available at the present time than coking coal, but this was only relative and there were signs of shortage even of non-coking coal.

Transport of raw material played a very important part in the overall economic efficiency of the industry and for this reason and because of the possible inadequacy of coal supplies it might be that the industry would develop along the lines of using non-coking coal near its source at the pithead and using oil at the big seaport centres of population.

Mr. G. W. Lee said : We have listened with very great interest to three most able papers dealing with the future of coal in regard to its classical use as a main source of energy in this country, and also as a means of providing raw materials for the chemical industry. Dr. Idris Jones and Dr. Holroyd have both stressed the importance of coal as a starting point for the Iron and Steel Industry of the country and they referred to the problems which we shall encounter in the future in continuing to provide a satisfactory raw material, i.e. coke, for use in the blast furnace.

Dr. Idris Jones in particular has referred to the important work which the National Coal Board are now carrying out at their research establishments to find new methods of treating and carbonising those coals which will be increasingly available in future years, and he has spoken of the efforts to provide a satisfactory solid smokeless fuel to replace coal for normal household purposes. I am sure that in working on such novel methods his industry is proceeding on the right lines, but Dr. Idris Jones has been careful to point out that even when the technical problems of new processes have been solved, the economic feasibility of carrying them out still remain to be proved. Under present-day conditions the introduction of extra stages in the carbonisation process, whether they be oxidation or briquetting processes are bound to introduce increased costs which would appear to make them prohibitive to operate. The coke oven process, as it is operated in this country at the present time, provides one of the most efficient methods we know of carbonising coal and yet under present economic conditions, barely holds its own. The introduction of fresh stages in the carbonising process would clearly render it uneconomic. Dr. Idris Jones has referred to the high capital cost of modern carbonising plant and also to the inherent limitations of coke ovens. It is true that modern coke ovens may be said to have taken shape twenty-five years ago when the last big surge in coke oven design and development, which was centred round the introduction of the silica oven, took place. The plants which were built in that period have reached, or are now in the process of reaching, the end of their useful life and the coke oven industry has therefore been faced since the war with the problem of rebuilding on a large scale, involving expenditure amounting to many millions of pounds. At that stage we were obviously setting the pattern for the next twenty to twenty-five years ahead and it was therefore most important to see that in this rebuilding programme advantage was taken of any new processes and all known and proved features of design. I do not think, and in this I believe I am supported both by Dr. Holroyd and Dr. Idris Jones, that the iron making process as we now know it will alter very appreciably in this country during the coming twenty-five years, because, after all, the modern blast furnace is a highly efficient instrument and I see little chance of the blast furnace or the coke oven being superseded by radically different forms of appliances during this time. This, of course, is an important conclusion with which I am sure Dr. Idris Jones agrees, but it does not detract in the slightest from his contention that new methods of dealing with coals which have hitherto not been used by the coking industry, must be developed. The coking industry itself, is, of course, doing everything possible to see that it remains efficient and adapts itself to the changing circumstances. The papers before us have stressed that the diminishing reserves of the best coking coals in this country will cause embarrassment in the years ahead, but we are, as Dr. Idris Jones indicates, seeing what we can do by techniques such as blending to improve and control coke quality, to conserve the reserves of the best coking coals and widen the range of coals which can be used for coke making. Much research on blending still remains to be done if the best is to be made in existing plants of the country's coal resources. The primary aim of this work is to establish some reliable measure o.

blending propensities and to develop a theoretical basis for blending which would eventually supersede the empirical methods now used.

The industry is expanding on what may be called its traditional or classical lines and I would say that Dr. Holroyd's estimate of an increase of capacity at the rate of 5 per cent. per annum is about correct. At the present time we carbonise in coke ovens some 26 million tons of coal a year, which is approximately 13 per cent. of the total coal mined in the country. This yields about 18½ million tons of coke together with by-products, and about 280,000 million cubic feet of gas per year.

I have referred to this large production of gas because, as Dr. Dent has indicated in his paper, the problems of gas supply for town purposes by the gas industry and the coking industry are of an intricate, interwoven nature and the tendency of the gas industry to forsake their traditional policy of being a two fuel industry, i.e. of producing both gas and coke, will have repercussions on the national fuel balance. Dr. Idris Jones has already indicated the methods by which he thinks a good solid smokeless fuel for domestic purposes will be produced in the future.

He has referred in his conclusions to the possibilities of controlling the type of solid material resulting from coal pyrolysis and has illustrated this by reference to the production of a very large range of reacttivity of coke as measured by the CAB test. I should perhaps emphasise that the coke oven plant was not developed as an instrument for the production of reactive coke, but there is no doubt that it can produce a solid smokeless fuel well suited for water heating and space heating purposes. In fact we envisage that with the present programme of coke oven building in this country, relatively large quantities of coke will become available for domestic purposes. Coke ovens cannot, however, under present conditions supply a fuel which is ideal for burning in any type of open grate, and it is here that the forward researches of the National Coal Board will fill a very pressing need.

The problem of seeking a solution to combat the decreasing supplies of good quality coking coals is not confined to this country but is world-wide, and is particularly acute on the continent of Europe. The Organisation for European Economic Co-operation proposed in 1950 through their French and German delegates that a working party should be established to study processes for producing coke by methods other than by the modification of the normal coking process.

I would like to emphasise that nothing in the deliberations of this O.E.E.C. committee leads us to the conclusion that we in this country are behindhand in either our research or our development work in regard to the treatment and pyrolysis of coal.

Dr. Schäfer said : The coal industry is interested in suitable gasification processes to meet the demand for gas without increasing the production of coke. The main question to be answered is :

> What type of gas is wanted ; the chief consideration being low or high calorific value gas.

In answering this question it should be realised that a therm of low calorific value gas can be produced at lower cost than a therm of high calorific value gas.

This means that for all purposes for which a lean gas *could* be used, it *should* be used. A lean gas is sufficient to heat coke ovens, retorts, many industrial furnaces, etc. For these purposes rich gas, mainly coke oven gas, is used in many works because coke oven gas used to be a by-product which was sold at a comparatively low price. Coke as the main product has a high price. The ratio of the coke and gas prices was—and still is—such that it is economically impossible to convert the heat contained in coke into heat in gas, even if only a lean gas is required. About 90 per cent. of the total cost of normal producer gas is the cost of fuel determined by the price for coke. This means that as long as there were only processes known by which costly coke could be gasified there was no economically sound possibility to replace COG (coke oven gas) with lower grade gas.

The present stage of development of gasification processes already permits the profitable replacement of COG which can then be used for purposes for which the supply of a rich gas is essential, for instance

town's gas. As the cost of fuel is the decisive factor in gasification, the recently developed processes are based on the use of cheap coal. The extreme method in this respect is the gasification of washery refuse. The most suitable equipment for this is the Hubofen of the Lurgi Company in Germany. To obtain optimum results the fuel should have a calorific value between 2900 and 4300 B.Th.U./lb. If the washery refuse has a lower calorific value then middlings or coke breeze can be added to the washery refuse. A gas of about 120 B.Th.U./c.ft. L.C.V. is produced at a gasification efficiency of ca. 70 per cent. Based on German prices for fuel, steam, power, etc., the total cost per therm of the gas made is lower than the present selling price for COG at the coke oven plant.

The second method which in my opinion can be applied to replace COG for underfiring coke ovens, etc., is the gasification of coke fines and coal fines on the basis of the Flesch gasification process. The fuel used may have a high ash content and a size smaller than 6 mm. The gas produced has a L.C.V. of about 140 B.Th.U./c.ft., the gasification efficiency being ca. 85 per cent. Based on German price conditions this gas is about 20 per cent. more expensive than that made in a Hubofen but still lower in price than COG.

In Germany there are some more processes under investigation with the aim of producing cheap gas suitable for replacing COG—for instance slagging producers. For the purposes so far discussed the results are in my opinion not quite as promising as those mentioned previously. Efforts have also been made to produce a rich gas by suitable equipment other than coke ovens or retorts. In that line the Lurgi pressure producer has proved to be most successful. Seven plants have been erected or are just being erected for a production of 5,500,000 Nm^3/day which is slightly more than 200,000,000 c.ft./day. The upper calorific value of the gas made varies between 400 and 470 B.Th.U./c.ft., and depends mainly upon the type of coal used. The highest calorific value has been obtained from lignite or brown coal.

Another interesting method for the production of rich gas is the so-called "Fine Pebble Circulation Process" of the Ruhrgas-Lurgi Co-operation. Whilst the preliminary investigations were made in the U.S.A. and by I.C.I. in England, Ruhrgas-Lurgi made some changes which improve the economical basis. For instance, the expensive pebbles have been replaced by the circulation of ash and coke which are formed in the process and the aim of the method has been confined to produce a rich gas equal to 580 B.Th.U./c.ft. instead of a synthesis gas. Synthesis gas requires considerably more heat which is difficult to provide by the circulation of a heat carrier.

Other firms in Germany are working on methods to replace the coke and ash as a heat carrier by using circulating gas. All these processes produce fuel gas, waste gases and coke which have to be used. The aim is to use the waste gas and the coke in boiler plants.

There are also pilot plants and investigations being made in Germany on slagging producers operating under pressure. In this case the aim is to produce a cheap synthesis gas which can be used to produce methane and liquid products on the basic of the Fischer-Tropsch-process. I believe that in England also there is some interest taken in these methods and investigation work is being performed. From some points of view this development is very attractive because it is possible now to use very low grade fuel with respect to ash and size in slagging producers and the throughput is very high which means the capital cost per unit of gas made is rather low. Recently in Germany, there have been considerable efforts made to secure a further reduction in the cost of gas by producing iron simultaneously in slagging producers. It is interesting in this respect that a very high grade coke—a so-called iron coke—can be made by mixing iron-ore fines with coking coal of low grade caking quality. Investigations for producing iron coke and gasifying it have been made on a large scale in the Ruhr area.

Dr. G. M. Lees said that there seemed to be an implication behind the various papers that the location, quantity and quality of our coal resources are reasonably well known. He wished to emphasise, and to emphasise strongly, that there are still good prospects of further discovery in

many parts of the country, perhaps even under the City of Oxford. The grade of coals cannot be anticipated, but it is possible, for instance, that good coking coals may be found to offset the inadequacy of the present proved reserves which was one factor in stimulating research on gas making from coals inherently less suitable.

The most promising areas are in Gloucester, Wilts., Berks., Surrey and East Anglia, but also elsewhere. Whether or not any new coalfields were developed in the near future would depend on many considerations of economics and location, but it is essential for forward planning that the facts should be known.

At present the Coal Board has an active drilling programme for exploring the extensions of the known fields, and has had some notable successes, and the Geological Survey has a grant for borings of geological importance, but the testing of areas for possible coalfields is only one of their objectives. The grant is quite insufficient to make much impression on the problem as a whole within a reasonable span of time, and in view of the importance of the results there is a very strong case for a more active programme.

Exploration for natural gas is now being actively pursued, initially on his recommendation, and the prospects of discovery are good, at least sufficiently so to justify fully the effort. The scale of expectation must, of course, not be exaggerated. Gas fields of importance will probably be found, but at best they will make only a modest contribution to the country's fuel problem as a whole.

Exploration for underground treasure, whether for oil, gas, coal or other minerals, requires a liberal outlook and a combined operation of geology, geophysics and drilling, and the results can be of the greatest importance even if the expected is not always found. In drilling for oil in North Yorkshire only gas was found, but the boring revealed the presence of a valuable deposit of potash salt. Recently in central France, at Lons le Saunier, a boring exploring for potash has discovered a new and quite unexpected coalfield.

Dr. R. Spence referred to the likelihood that by the end of the century most of the electrical power produced in this country will be generated from nuclear reactors. He thought it quite possible that it may also, by then, be the cheapest form of energy.

In considering the long-term future of coal, would it not, therefore, be wise to take this possibility into account? The application of relatively cheap electrical energy to coal processing might lead to some interesting developments and the further possibility of the use of nuclear radiation from the fission by-products of the power industry might be worth examining.

Dr. A. Parker (Director of Fuel Research D.S.I.R.), said that at present rates of production there is enough economically mineable coal in Great Britain for about 200 years. Difficulties of production will increase and the quality of the available coals will decrease during this period. There is a shortage of the best coking coals for making metallurgical coke. It is also said that there will be a relative shortage of other coking and gas making coals. In his opinion there need be no real shortage of such coals in comparison with coals of other types, if the coking coals were not used for other purposes for which they are not necessary, and if the practice of blending coals for the production of good coke were extended. Unless coal production can be increased, it will not meet the increasing demands for power so necessary if we are to increase productivity to maintain our standard of living. We are already importing so much oil that we are now net importers and not net exporters of fuel. Power from nuclear fission will come gradually and we must harness water power, wind power, and other sources as far as economically practicable.

With regard to the gas industry, in his opinion, flexibility in methods of gas production must be the guiding principle, with all the changes in availability of fuels that must occur more rapidly in the future than in the past.

THE INTEGRATION OF THE GERMAN REFUGEES, 1945–1953[1]

by

R. E. H. MELLOR

THE Second World War produced a migration of peoples in Central and South-eastern Europe far outstripping the great *Völkerwanderungen* of the Dark Ages. Although the new boundaries after the First World War caused some migration, it is only since 1939 that movement has been on a very large scale. Among other peoples, over sixteen million Germans have been forced to flee or have been expelled from their homes in Central and South-eastern Europe: the fate of three million is unknown. At the census of 1950, a fifth of the 47·5 million inhabitants in Western Germany were refugees from annexed German lands beyond the Oder-Neisse or from German colonies in the Danube lands, the Baltic countries or Czechoslovakia ; and there is a continual stream of political refugees from the Soviet Zone, where nearly a quarter of the population is refugee.

The refugees who, unlike normal immigrants, form a complete cross-section of society, were forced into a disrupted country. Germany lost roughly 20 per cent. of her food-growing area and 10 per cent. of her heavy industry in the extensive annexed areas beyond the Oder-Neisse. War brought industry to a standstill, partly because of destruction, partly by the shortage of raw materials, and the imminent threat of dismantling. Agriculture, with insufficient fertilisers, replacements, and labour, was called to produce food for the bulk of the population. The refugees have, therefore, been an excessive burden ; but at the same time they have brought new skills and ideas which have proved a stimulus to local people, and have perhaps acted as a factor in the surprisingly rapid recovery since 1948.

[1] Address delivered to Section E (Geography) on Friday, September 3, 1954, during the Oxford Meeting of the British Association.

The humane transfer of German population from Poland, Hungary, Czechoslovakia, foreseen at Yalta and planned in Article XIII of the Potsdam Agreement, had already been invalidated by the time of publication by the mass flight and expulsion which had begun in late 1944. Even countries not included in the Potsdam Agreement had seized the opportunity to rid themselves of unwanted German minorities. The first indication of how great the flood was and of its influence on population structure within Germany's postwar boundaries came in the Four Power census of 1946. Although the total population under German control fell between 1939 and 1946, the population living in the 1946 boundaries (53 per cent. of the 1939 area) had risen by over 10 per cent. Non-refugee local population had declined by almost three million because of the heavy war losses and the steep fall in the birth rate, so that growth had been accounted for by 5·6 million refugees from annexed German lands and 4·1 million Volksdeutsche refugees. This number greatly exceeded the estimates made at Potsdam. In West Germany, the present Federal Republic, the pattern had been similar : population had risen from 39·4 million in 1939 to 43·7 million in 1946, an increase of 13·4 per cent. By 1950, the population had risen further to 47·9 million (an increase of 20·9 per cent. on 1939). Unfortunately, comparable statistics are not available for the Soviet Zone.

There had also been a considerable change in the age and sex structure of population, which had hardly recovered by 1939 from the First World War. In Western Germany, the average age of 31 in 1939 had risen to over 33 by 1949 ; and in the Soviet Zone, because of the strong outward migration of young people for

political reasons, this was no doubt higher. At the same time, the number of people over 65 had risen by 50 per cent. The greatest decrease had been in the age groups between 20 and 40, the economically and militarily, as well as demographically, most productive groups. The disproportion of women to men in age groups over 40 in 1939 had spread downwards, and was especially high in the 20 to 40 groups. Early beliefs ascribed this older and more female population to the refugees; but the carefully made Federal census of 1950 in Western Germany, where the number of refugees had risen from six million to over nine million, did not support this view. Refugee groups, with few exceptions, had a healthier age sex structure than local people (Table I). After the very low birth rate and abnormally high death rate of 1945–1946, the refugees, by 1950, had a higher rate of natural increase than non-refugees, standing at 10 per 1,000 compared with 6 per 1,000. 1950 was the first year since the middle war years that population growth was by natural increase and not migration.[2]

TABLE I

Age and Sex Structure of West German Population, 1950[1]

Age Group	*Sex*	*Refugees* (*in percent of total in each column*)	*Remaining Population* (*in percent of total in each column*)
Under 6	Male	9·25	8·92
	Female	7·83	7·49
	Total	8·50	8·16
6 to under 14	Male	15·99	14·65
	Female	13·68	12·38
	Total	14·77	13·44
14 to under 18	Male	6·90	6·68
	Female	5·94	5·67
	Total	6·39	6·14
18 to under 21	Male	5·01	4·62
	Female	4·27	3·91
	Total	4·62	4·24
21 to under 25	Male	7·22	6·09
	Female	6·27	5·61
	Total	6·72	5·84
25 to under 45	Male	28·93	25·75
	Female	30·92	29·85
	Total	29·98	27·93
45 to under 60	Male	17·04	19·47
	Female	18·67	20·34
	Total	17·90	19·94
60 to under 65	Male	3·37	4·38
	Female	4·35	4·80
	Total	3·89	4·63
Over 65	Male	6·29	9·44
	Female	8·07	9·89
	Total	7·23	9·68

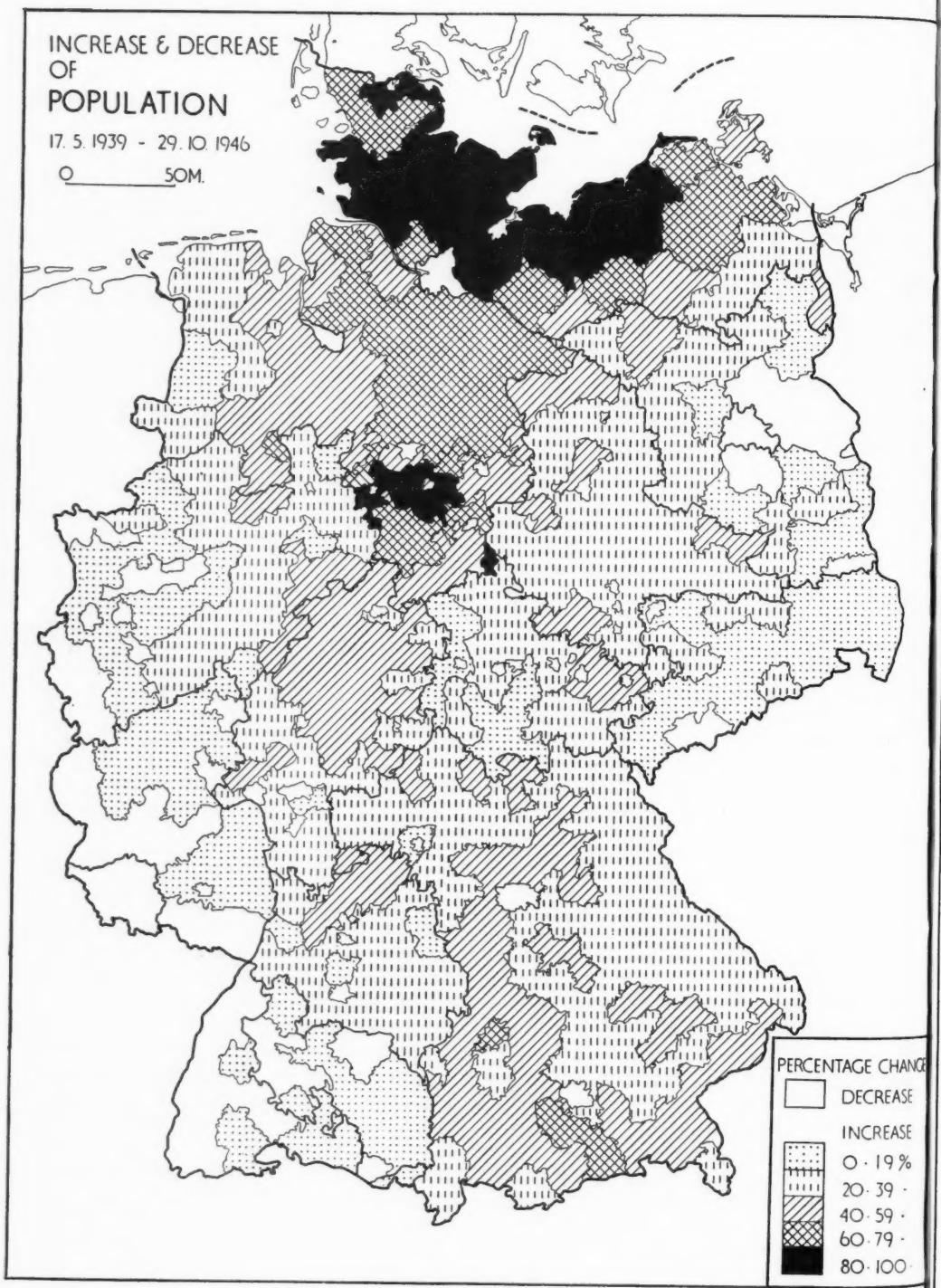
Heavy bombing and invasion in Germany drove people from the towns to 'safe' areas in the countryside, and from

the frontier districts into the heart of Central Germany, the North-west and Bayern. The countryside, already crowded with evacuees, also became the chief recipient of refugees. The results of this movement, the surprising growth in the Baltic coast and the North-west, the losses in the Ruhr and Rhenish industrial districts, the frontier districts along the Rhine, and the ' city-states,' stand out clearly in Map I. Growth in parts of Sachsen, Sachsen-Anhalt, and in Württemberg-Baden, had been entirely the result of refugee influx, as there had been a decline in the non-refugee local population. The proportion of refugees to local people varied widely : in the Baltic coast and the North-west, there were large areas where refugees formed almost half the population or more (Map II) ; elsewhere in Central and South-eastern Germany they formed between a quarter and a third of the population. Although quantitatively considerable in the Ruhr and Rhineland industrial districts, they formed under 10 per cent. of the total population. They were particularly few in the French Zone, forming under 4 per cent. of the population, because the French as non-signatories of the Potsdam Agreement refused to accept refugees.

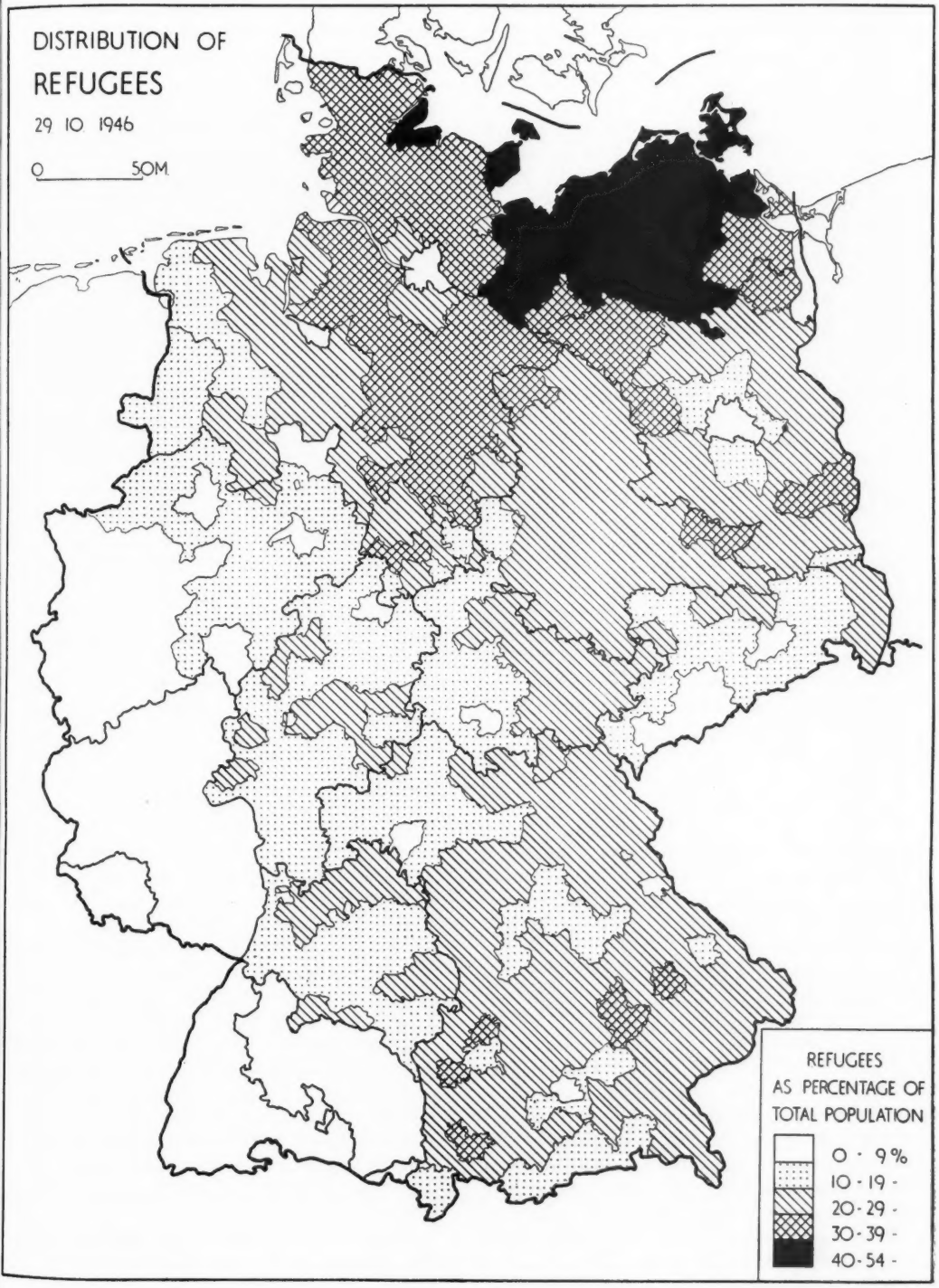
In many parts of the country, refugees arrived at up to 8,000 a day, and the first need was shelter, food, and some work. Because of destruction in the towns, most accommodation was usually found in country districts. Decentralisation, disorganisation of communications, and political difficulties, left local authorities ill-equipped to deal with a movement of which they had no previous experience. The elaborate machinery which would have existed had the Potsdam Agreement been carried out systematically never really started. After the abolition in 1945 of the Nazi organisation for dealing with the first refugees, the task fell to Zone and Land governments, each developing its own procedure. There was not even a common definition of refugee status. Each Zone tried hard not to accept more refugees than was necessary. Everywhere, however, the aim was the same ; to give the refugees the first essentials of life and to prevent the formation of a dual society by ensuring that refugees and local people were equal in every possible way. Integration has overwhelmingly been achieved by refugees and non-refugees living together and helping each other. Great has been the effect of refugees trying to rebuild what they have lost by moulding themselves economically and socially into local life. To speed this natural process, the government has given generous aid for rehabilitation and resettlement, not only to assist refugees but also to spread the load more evenly between all parts of the country and all sections of the population. This has been a fundamentally different approach to that of Russian dominated Eastern Germany, where refugees have been accorded no special consideration and have had to take an equal chance with local people. Even the term ' refugee ' (and its sometimes preferred equivalent ' expellee ') has been replaced by ' resettler ' (Umsiedler).

Refugees come from many different backgrounds. Fortunately Reichsdeutsche predominate—there were over 4·5 million in the Federal Republic alone in 1953, mostly from Silesia and East Prussia. They have been resettled with comparative ease as they are used to a life little different to that of their new homes. In contrast, the Baltic Germans, traditionally land-owners and professional people, feel their ' de-classed ' position more acutely. Likewise, the partially degermanised Volksdeutsche from Volhynia, the Pripet, and South Russia, find life strange in Western Germany : magyarised and slavicised descendants of colonists who left German lands in the Middle Ages have little feeling for ' Deutschtum,' rarely comprehending the reasons for expulsion, and cherishing only their own ' Heimat ' far away. Some groups have suffered more than one transfer since 1939, with consequent psychological repercussions. Although any one group rarely dominates in a particular area, the larger bodies from, for example, Silesia or East Prussia are usually sufficiently numerous to be able to live in colonies which break down any feeling of isolation. The smaller groups, from Danzig or the former German Volga Republic, usually widely scattered, feel themselves much more in an alien world.

Integration has not been hindered by the problem of ' cultural levels ' found in


INCREASE & DECREASE
OF
POPULATION
17. 5. 1939 - 29. 10. 1946
0 50M.
PERCENTAGE CHANGE
DECREASE
INCREASE
0 · 19 %
20 · 39 ·
40 · 59 ·
60 · 79 ·
80 · 100 ·

MAP I


DISTRIBUTION OF
REFUGEES
29 10 1946
0 50M
REFUGEES
AS PERCENTAGE OF
TOTAL POPULATION
0 · 9 %
10 · 19 ·
20 · 29 ·
30 · 39 ·
40 · 54 ·

Map II

migration into Israel, for there are closely comparable standards between local people and refugees. With refugee families rather larger than local West German families, refugee children in the country districts of Schleswig-Holstein and Niedersachsen make local children a minority, with consequent influence on social interests and the curriculum in schools. In higher education, refugees have less than their share : in universities, only 8 per cent. (instead of over 15 per cent.) of the students are refugees. This is an inequality which may have serious repercussions in ten or fifteen years. In political life, refugees have reasonable representation up to Kreis level ; but in some areas their interests in national affairs are overshadowed by strong non-refugee groups. Nevertheless, a not inconsiderable number of refugees have reached the Bundestag and even become Ministers. In their frustration and disillusionment, refugees have occasionally turned to neo-nazi or radical groups, which neither have their welfare at heart nor really mirror true refugee sentiment.

Among the greatest forces helping successful integration has been religion. Refugee groups usually have a strong confessional bias : and the average German country parish is generally either strongly Protestant or Roman Catholic. In Western Germany, with its complex distribution of the major confessions, the interplay of religious forces in integration has been stronger than in the Soviet Zone, where suppression and the acceptance of dominantly Protestant refugees in Protestant Gemeinden have reduced its importance. Protestant East Prussians and others have tended to gather in the Protestant North, whereas Roman Catholic Silesians and refugees from Czechoslovakia have settled more in the Catholic Hessen and Bayern. Refugees isolated in a parish of a different confession to their own feel their loss more acutely, particularly the devout German peasant. Cases are known of migration of refugees to parishes of their own confession despite worse material living conditions. This has been comparatively common from the strongly Catholic Münsterland to the Protestant Ravensberg and Lippe. A sudden inflow of refugees has sometimes upset delicately balanced social forces. The German churches have done all in their power, without distinction of creed, to alleviate distress.

The most powerful and successful factor in integration has been intermarriage and the mixing of refugee and non-refugee children. The total number of mixed marriages is not known, but is thought to be increasing yearly. Out of 153,000 marriages made by refugees in 1951, 109,000 were mixed. A special survey in Nordrhein-Westfalen showed that the marriage rate of refugees was higher than among the non-refugee population. Marriage between refugee men and local women has been more frequent than the reverse combination. Refugee men have sought local girls with good connections, often the opening into a family business. Local families who have lost sons have favoured such unions as a means of handing hard-won inheritances to men traditionally known for their diligence. Refugee girls, without good connections, have been less favoured as wives by local men. The de-classed position of refugees has been of little importance : social standing before flight has invariably been the deciding factor. Marriage has been more common between local people and Reichsdeutsche refugees than the more divergent Volksdeutsche groups. Children of any union are given the status of the father, except illegitimate children who take that of the mother. Refugee children have very quickly merged with their new homelands, despite attempts by various refugee organisations to keep alive the feeling of the 'Heimat.' A not inconsiderable proportion of the 'refugees' have in fact been born in Western Germany ; for example, in Schleswig-Holstein, in 1950 almost 5 per cent. of the refugees were children born there after the flight of their parents. It is questionable whether children born after flight, and indeed refugees who were under about 20 at the time of flight, would return to their 'homelands' even if given the chance.

Failure to mix with local people has been influenced by the attitude of local people and the feeling of 'de-classing' which most refugees experience. Table II is a self-explanatory summary of the

TABLE II

Changes in Social Status of Refugees before and after Flight[3]

Change of Income	Before Flight	After Flight
Up to 200 Marks per month	50%	93%
200–500 Marks per month	39%	11%
Over 500 Marks per month	12%	1%
Change in Occupational Standing		
Labourers	45%	87%
Employees	20%	7%
Civil Servants	7%	3%
Self-employed	26%	3%

degree of this 'de-classing.' The figures which apply to one part of Westfalen are typical of the whole Federal Republic. In order to assert themselves and prevent discrimination against them, refugees have formed regional associations (Landsmannschaften), which also keep alive old customs and traditions. Some German authorities claim, however, that under half the refugees belong to such bodies.

Housing conditions have also accentuated the de-classed feeling among refugees. Germany lost a fifth of its housing during the war: in some towns more than half was lost. The number of persons per dwelling rose from 3·7 in 1939 to 5·3 in 1945. Estimating four persons per dwelling, there was a deficit of over 2·5 million units. Refugees have had to take whatever has been available. In the country, they have lived in barns, farms, and even unused defence works; and the situation has been little better in towns, where air-raid bunkers, cellars and attics have been used. Nearly every house and flat has had to be divided into two or more dwellings. In parts of Schleswig-Holstein and Niedersachsen, over half the refugees lived in sub-standard accommodation. Even after considerable rebuilding, the refugees were still badly housed in 1953. Only 30 per cent. were tenants of normal flats or houses, but 58 per cent. were sub-tenants (i.e. living in divided accommodation). Among non-refugees the corresponding figures were 77 per cent. and 20 per cent. Living under bad conditions, it is not surprising that frictions arise between refugees and non-refugees over the use of shared bathrooms and kitchens.

Finding refugees permanent and rewarding jobs has been difficult. Table III shows that the refugees have a markedly different occupational structure to that of the Federal Republic.

Although three-quarters of the refugees live in country districts, under half have occupations associated with country life. Few refugees have managed to establish themselves in their old professions and jobs; and where this has been achieved, they invariably hold inferior positions (Table II). Persons holding Czech, Polish, or old Austrian trade qualifications find potential employers will very often not accept them, which puts refugees at an immediate disadvantage in competition with non-refugees. Despite equality in law, a local applicant, either through favouritism or contacts, usually secures the job. The refugee has better chances in the impersonal life of the towns than in the parochial countryside. His will to work makes him sometimes unpopular among non-refugee workmates, for refugees will work for little to help rebuild their shattered lives and as a psychological defence against the past.

Despite heavy war losses, the German labour market has about five million more hands than in 1939, though there has been no corresponding big increase in

TABLE III

Occupational Structure in Federal Republic and Annexed Territory in 1939[4]

Occupation	Federal Republic	Silesia	East Prussia	Brandenburg
Farming and Forestry . . .	26·2%	29·7%	49·6%	33·0%
Industry and Handicrafts . .	40·5%	42·4%	25·4%	39·6%
Trade, Transport . . .	16·6%	17·1%	14·6%	16·9%
Public Service	12·8%	8·3%	8·4%	8·5%
Domestic Service . . .	3·9%	2·5%	2·0%	2·0%

the number of jobs open. Although by 1953 the number of refugees unemployed had sunk to just over 300,000, these were mostly permanently unemployed. Of over 800,000 unemployed persons in the Federal Republic, refugees formed 37 per cent. This figure is far above their proportion of the total population; and 4·5 per cent. of the refugees were out of work, compared with only 2·2 per cent. of the remaining population. Unemployment was much higher in Schleswig-Holstein and Niedersachsen than the national average, and refugees formed roughly half of the total unemployed.

Opportunity for re-establishment has varied in various occupations. Agriculture has offered the least chance since the currency reform of 1948 made it no longer worthwhile merely to work for food. This has affected such dominantly agricultural refugee groups as the East Prussians very severely. The intensely cultivated German countryside, with its many small farms in the West, offers little scope for a land reform. The Soviet Zone created some 64,000 small holdings out of 2·7 million hectare of requisitioned land, shared among refugees and local people alike; but experience of falling production and collectivisation has been not reassuring, though expropriation continues. According to an Economic Cooperation Administration Commission, 500,000 hectare could be reclaimed for farming in Western Germany. Much of this land is in the Ems Basin, the North Sea Coast, and the Lüneburger Heide, in the overcrowded Land Niedersachsen, where 22 per cent. of the refugees lived in 1952. In the Rhineland, former tanning oak groves might be reclaimed; and everywhere reduction of the forests might offer further new land. It has already been seen what can be done with moors in Holland. Further employment might be created by increasing yields, using more machinery, and rearranging holdings. Even though families have been settled in clearings in the Reichswald and other refugee farmers have been put into 'auslaufende Höfe' by public funds, the progress made has been generally unsatisfactory. Under a tenth of the deserving cases have been satisfied. The refugee farmer, however, used to very different methods in his homeland, does not always make an ideal tenant in Western Germany.

The greatest changes since the revival of economic activity with the currency reform of 1948 have been in industry. Specialised industries, affected by wartime destruction and postwar dismantling, have until recently found it hard to employ even their own local workers. Basic heavy industry and the light consumer goods industries have provided the main pool of jobs for refugees. The coal-mining industry, which was one of the first to be restarted, was particularly short of workers, and has attracted to it both young active refugees and experienced refugee Silesian miners by the special incentives of food and housing offered. About 10 per cent. of the labour force in the mines is refugee. The textile industry, which has been substantially expanded by refugee firms, has over a third of its labour force composed of refugees. The older labour force, the decreased productivity per worker from older machinery and wartime strain, has made most industries need a larger number of workers than in 1939 to produce the same quantity of goods.

In their homelands some refugees had developed special skills which they brought with them. The new 'refugee' industries manufacture world-renowned goods, mostly light consumer articles in big demand. Some of the new products are among Germany's most important dollar earning exports. These industries have been without appreciable non-refugee competition, but they have had to face problems of collecting together former workers, capital, and equipment. The new industries have in many instances to work from unsuitable sites away from the main arteries of business and transport. For example, the glass-makers from Bohemia have found it hard to obtain in Western Germany raw materials of the right quality. Competition has come from firms in their homelands, producing similar but inferior quality articles with heavily subsidised non-German labour at abnormally low prices. Bohemian glass firms are now spread over Bayern, Hessen, and around Cologne. Sudeten textile firms are common throughout the South, while those from Łódź have brought new life to the depressed naval port of

Wilhelmshaven. The famous Zeiss works of Jena are now near Stuttgart. Refugee firms employ only about 15 per cent. of their 1939 numbers, though they are growing fast. Some branches (e.g. musical instrument makers) already employ more than half their 1939 numbers and, in bringing diversification to overspecialised districts, they have been welcomed by local authorities.[5]

Former independent businessmen have found it hardest to recruit new capital; and the refugee bank has far more claims on its resources than it can cope with. The dental and medical professions, greatly expanded for war needs, are also overcrowded, so that prospects are much poorer than pre-1939. It is now hard to build up a good practice, though there have been some excellent opportunities overseas for German medical men. The percentage of independently employed persons among refugees has fallen greatly between before, and after, flight. There is even sharp competition for ordinary office jobs from war wounded, war widows, and single women with little prospect of marriage.

It was clear from the extremely uneven distribution of refugees shown in Map II that any lasting and completely successful integration of refugees would involve either large rehabilitation and development schemes in the crowded districts or an extensive movement of refugees from Schleswig-Holstein, Niedersachsen, and Bayern to Länder with a lower proportion of refugees among their population. It has always been agreed that to give refugees an opportunity to work to regain their losses is better than Public Assistance Relief, however generous it might be. Early attempts to distribute the burden more fairly failed, because the French and Soviet Zones would not co-operate with the British and American Zones. In 1947, a measure of unison was reached to allow the reuniting of separated families. Allied movement restrictions, the prevailing unsatisfactory health and housing conditions in towns, and the depression in industrial areas, coupled to the lack of genuine will to co-operate among Zones and Länder, hampered any great achievement. The currency reform of 1948, with its consequent rise in unemployment and clamour for economically rewarding jobs, stressed the need for a strong central body to form and carry out long term policy. This need was settled by the creation after the formation of the West German Republic of a Ministry for Refugees.[6]

Policy has been to finance rehabilitation courses to equip refugees, especially the younger ones, to meet the changed conditions; to provide relief for aged persons and unemployables; and to offer help in finding jobs and houses for refugees ready to move to the Länder with small refugee burdens. Although transports have been arranged, private migration, with government aid, has been encouraged. Unfortunately, a distressingly large share of the money available has had to be devoted to relief rather than rehabilitation work. Work has also been hindered by the constant flow of refugees seeking asylum from persecution in the Soviet Zone, most of whom need immediate monetary aid. Slowness has arisen from ensuring that integration already achieved has not been undone by resettlement plans and that local people and long established refugees in receiving districts do not feel that the migrants are unfairly favoured.

Plans include the expansion of refugee industry in the depressed former naval ports of Northern Germany and throughout the countryside, which will be aided by extension of the electricity grid and improved communications. The possibility of land reclamation in these areas has already been noted. It is hoped to swell the trade of Bremen, Hamburg and other ports, which ought to provide more jobs for people living in the crowded countryside around. A major project is the building of an autobahn to link these ports with Hanover and the Ruhr. In the South-west, plans include the building of an autobahn from Karlsruhe to Basel and the making navigable of the Rhine as far as Schaffhausen, to provide better links with the scattered semi-domestic industry of the Black Forest and Bodensee littoral. This form of industry is well suited to refugee employment. All Länder have plans to encourage refugee tenancy of farms: the E.C.A. Commission estimated that these would provide 38,900 families with full-time farms, 24,400 families with part-time farms, and small holdings for 14,900 families.[7]

That these measures and the process of natural integration have already changed the distribution of refugees, whose numbers continually increase, is shown in Table IV. Since 1946 the increase in refugees in the western Länder of the Federal Republic has been marked, while the growth has been small (below average) in the over-crowded Länder of Schleswig-Holstein, Niedersachsen, and Bayern. It is proposed to move over 300,000 refugees eventually from these Länder. The large growth in Bremen and Hamburg is a statistical reflection of a general trend of movement from the country to the towns which are becoming increasingly attractive. The refugee burden, as revealed in columns 3 and 4 of Table IV, is still not equally shared between the Länder in proportion to their share of the total population, so that there is still scope for further movement. It would be interesting to compare this situation with Eastern Germany, for which there are regrettably no published figures.

A great deal remains to be done, but what has been achieved has exceeded the hopes of six years ago. The sometimes suggested solution of large scale overseas migration, except in a few cases, has not been necessary; nor would it help, because it would draw away young people, leaving an even top-heavier population pyramid than at present. Much of the speedy recovery of Germany, which has now placed it in the forefront of the European nations, must be attributed to the efforts and stimulus of the refugees, who again have benefited from this sudden upsurge in prosperity.

TABLE IV

Regional Distribution of Refugees, 1946 *and* 1952[8]

Land	Refugees in total Population		Refugees	Remaining Population	Increase/ Decrease in Refugees, 1946–1952.
	1946 %	1952 %	—as % of total in Western Germany (1952).		
	1	2	3	4	5
Schles.-H.	32·0	31·0	9·0	4·0	−7%
N. Sachsen	23·0	27·0	22·0	12·0	+23%
Bayern	18·4	21·0	23·0	18·0	+15%
Bremen	5·2	10·0	1·0	1·0	+127%
Hamburg	4·1	8·0	2·0	4·0	+150%
N.R. Westf.	6·0	11·0	19·0	30·0	+119%
Hessen	13·5	17·0	9·0	9·0	+36%
Rhld.-Pfalz	1·2	7·0	3·0	8·0	+606%
South-west :					
W.-Baden	15·0	17·0	8·0	8·0	
W.-Hohenz.	3·2	11·0	2·0	3·0	+74%
Baden	2·0	9·0	2·0	2·0	
Federal Republic	15·0	17·0	100·0	100·0	+38%

REFERENCES

1. Calculated from *Statistische Berichte*, Arb. Nr. VIII/20/7, Statistisches Bundesamt, Wiesbaden, 1952.
2. Summaries are given in :
   EDDING, F. : *Die Flüchtlinge als Belastung und Antrieb der westdeutschen Wirtschaft.* Kiel, 1952.
   Deutschland-Jahrbuch 1953 : 36 Kapitel : *Vertriebene und Flüchtlinge.* Essen, 1953.
3. Schulze-Westen : *Das Flüchtlingsproblem, Dortmunder Schriften zur Sozialforschung*, 10. Dortmund, 1949.
4. Figures issued by the Federal Ministry of Refugees.
5. DITTRICH E : *Die Wiedereingliederung der Flüchtlingsindustrien in die Wirtschaft der Bundesrepublik.* Bonn, n.d.
6. *Grundgedanken zu einem Bevölkerungsausgleich in der Bundesrepublik Deutschland*, Institut für Raumforschung. Bonn, 1950.
   Die Umsiedlung der Heimatvertriebenen in der Bundesrepublik Deutschland, Institut für Raumforschung, 1951.
7. E.C.A. Technical Assistance Commission on the Integration of the Refugees in the German Republic. Report issued in 1951.
8. *Deutschland-Jahrbuch* 1953 : 36 *Kapitel* : *Vertriebene und Flüchtlinge.* Essen, 1953.

INDEX to Volume XI, 1954–1955

Figures in heavy type preceding page references indicate the parts of *The Advancement of Science* in which references will be found.

Titles of communications are frequently abbreviated.

Account, Treasurers' statement and, 1953–4, **43**, 347
Acid soils and forest trees, M. V. Laurie, **43**, 364
ADAMS, Dr. A. R. D., Pathogenicity of 'entamoeba histolytica,' **41**, 91
ADRIAN, Dr. E. D., Localisation in cerebral cortex, **43**, 363
Science and human nature, **42**, 121
AGER, D. V., Faunal provinces, British upper Domerian, **43**, 360
Agricultural policy, British, economics of, G. R. Allen, **43**, 362
Agriculture, efficiency of medieval, Dr. C. S. Orwin, **43**, 365
industry and science, Dr. R. E. Slade, **42**, 251, **43**, 365
AHRENS, Dr. L. H., Elements in rocks and meteorites, **43**, 360
Alcohol formation in plants, Miss A. F. Ritchie, **43**, 364
ALEXANDER, W. B., Sewage farms and birds, **43**, 361
ALLEN, G. R., Economics of British agricultural policy, **43**, 362
Marginal farms, **43**, 365
ALLEN, Prof. P., **43**, 366
Alpine communities, growth form, Dr. F. H. Whitehead, **43**, 364
Ambitiousness among school-leavers, Miss T. Veness, **43**, 364
AMBROSE, Dr. E. J., Molecular structure of chromosomes, **43**, 361, 366
Amphibian metamorphosis, Dr. J. M. Dodd, **43**, 361
Amphioxus, nervous system, Dr. W. Holmes, **43**, 360
Analytical problems (by-products from coal), A. A. Smales, **43**, 360
ANDREWS, Dr. W. H. Horner, Research projects in malaria, **41**, 93
Anglesey, structure and succession, Prof. R. M. Shackleton, **41**, 106
Anglo-Saxon cemeteries, Thames Valley, Miss J. R. Kirk, **43**, 362
Animal behaviour, **43**, 368
Animal direction finding, Dr. H. W. Lissmann, Dr. D. I. Williamson, Dr. J. L. Cloudsley-Thompson, Dr. J. D. Carthy, **41**, 69
Animal language, Dr. N. Tinbergen, **43**, 363, 365
Animal populations and forestry, G. H. Thompson, **43**, 364
Anthropology, physical, Dr. J. S. Weiner, **43**, 362, 363
Anura, reproduction in, B. M. Hobson, **43**, 361
Aphids, colouring matters of, Prof. A. R. Todd, **43**, 359
Appetite instinct, J. G. Gordon, **43**, 361
Archaeology, Colonial, Sir Mortimer Wheeler, **42**, 203
in Oxford region, **43**, 362
in S. Ethiopia, G. W. B. Huntingford, **43**, 362
spectroscopic analysis, Dr. E. T. Hall, **43**, 363
Archaeological techniques, **43**, 362
Archaeopteryx and evolution, Sir Gavin de Beer, **42**, 160, **43**, 360
Arthropods, terrestrial, dispersal of, Dr. J. L. Cloudsley-Thompson, **41**, 73
Asexual reproduction, Prof. A. A. Boyden, **43**, 360
Atmospheric pollution and house heating, Dr. A. Parker, **43**, 363

BAILEY, Sir Edward, and MCCALLIEN, Prof. W. J., Slieve Gullion, **43**, 360
Mona complex in Lleyn, **41**, 108
BAKER, Dr. J. R., Golgi controversy, **43**, 360, 366
BARKER, Dr. J., and MAPSON, Dr. L. W., Respiration of plants, **43**, 364
Barley metabolism and glycollic acid, Dr. D. C. Elliott, **43**, 364
BARNES, Dr. H., Underwater television and marine research, **41**, 55
BARNETT, Dr. S. A., and MANLY, Miss B.M., Breeding mice below zero, **43**, 361, 367
BARRINGTON, Prof. E. J. W., Thyroid and evolution, **43**, 361, 367
BASSETT, Dr. D. A., Folds and cleavage of the Talerddig district, **41**, 108
BASTOW, D., Vehicle design for safety, **43**, 362
BATES, Dr. J. A. V., Localisation of voluntary movement in cortex, **43**, 363
BATEY, C., Printing and making of books, **43**, 362
Beaker period sites, N. Thomas, **43**, 362
BECKINSALE, Dr. R. P., Oxfordshire textile industry, **43**, 361
BEDFORD, Dr. T., Physiology of heating and ventilation, **43**, 363, 368
Beech, root surface fungi, J. S. Waide, **43**, 364
Beechwoods: Chiltern project, **43**, 365
Beef tapeworm, survival of egg, P. H. Silverman, **43**, 361
DE BEER, Sir Gavin R., Archaeopteryx and evolution, **42**, 160, **43**, 360
Behaviour, animal and human, Prof. A. Rex Knight, **43**, 364
Behaviour syndromes, B. A. Johnson, **43**, 363
BELL, P., Phylogeny, **43**, 364
BENTLEY, Dr. E. W., Sewer rat populations, **43**, 361
Bird photography, C. Newberry, **43**, 365
Black diamonds, **43**, 360
BLACKETT, Prof. P. M. S., Rock magnetism, **43**, 359, 366
BLACKMAN, Prof. G. E., Herbicides, **43**, 365
BLEANEY, Dr. B., Determination of nuclear spins, **43**, 359
Body form in man, Dr. J. M. Tanner, **43**, 363
BONDI, Dr. H., Modern theories of cosmology, **43**, 359
Bones, methods of dating, Dr. K. P. Oakley, **43**, 363
Books, printing and making of, C. Batey, **43**, 362
BOWDEN, Dr. F. P., Friction, **43**, 265
BOYDEN, Prof. A. A., Asexual reproduction, **43**, 360
Brachiopods, Lower Cretaceous, F. A. Middlemiss, **43**, 360
BRADFIELD, Dr. J. R. G., Electron microscope studies of protoplasm, **43**, 360, 367
BRADFORD, J. S. P., Discoveries from the air, Mediterranean, 1953–4, **43**, 362, 367
Brain and muscle, Prof. E. G. T. Liddell, **43**, 363
BRIERLEY, J. K., Mycorrhiza, **43**, 364
BRIGGS, Miss K. M., Folklore in 17th century literature, **43**, 363
British economy, changing structure, Prof. E. A. G. Robinson, **42**, 182
Broadbent, D. E., Conditioned responses, **43**, 364
BROWN, G. Spencer, Test of significance, **43**, 363, 368
BROWN, J. M. B., Site potentiality, **43**, 365
BROWN, Dr. J. R., Working conditions in home, **43**, 363, **44**, 415
BROWN, S. G., Whale marking, **43**, 360, 367
BRUCE, G., History of examination system, **43**, 365, 369
Bryophyte communities, Dr. E. V. Watson, **43**, 364
BUCKINGHAMSHIRE, Earl of, View of private owner in Chilterns, **43**, 365
Bünsowland, physiography, Dr. Marjorie M. Sweeting and Miss G. E. Groom, **43**, 361
Bupalus pinarius L., Dr. Myles Crooke, **43**, 364
Burhs, ninth and tenth century, Mercia and Wessex, Dr. F. T. Wainwright, **43**, 362
Burramys *Broom*, fossil marsupial, W. D. L. Ride, **43**, 360
BUTLER, Dr. J. R., Trace elements in sedimentary rocks, **43**, 360

Cable, cross-channel power, F. J. Lane, **43**, 362
CAMPBELL, Dr. B., Co-operative field work, **43**, 365, 369
Caratacus in the Cotswold, Mrs. E. M. Clifford, **43**, 362
CARDON, Dr. P. V., Opening up new frontiers, **43**, 365
CARLISLE, D. B., Moulting in crustacea, **43**, 361
CARMICHAEL, Dr. E. A., DIX, Dr. M. R., HALLPIKE, C. S., Lesions of cerebral hemispheres, **43**, 363
CARTER, Prof. C. F., Science and industry committee, **43**, 362, **44**, 404
CARTHY, Dr. J. D., Role of vision in insects, **41**, 75
Cell morphology, **43**, 360
Cells, study of reptilian visual, G. Underwood, **43**, 360
Centromere, the, Prof. P. T. Thomas, **43**, 361
Cerebral cortex, localisation in, Dr. E. D. Adrian, **43**, 363, 368
Cerebral hemispheres, lesions of, Dr. E. A. Carmichael, Dr. M. R. Dix, C. S. Hallpike, **43**, 363
Cetaceans, Dr. F. C. Fraser, **43**, 360
CHAYEN, Dr. J., Desoxyribose nucleic acid nature of gene, **43**, 361
Chemistry, new ideas in, Sir John Lennard-Jones, **42**, 136, **43**, 359
outlook in organic, Prof. C. K. Ingold, **43**, 359
CHESTERMAN, W. D., Underwater films, **41**, 54
Child neglect, psychological factors, Dr. G. R. Twiselton, **43**, 363
Chilterns project, O. J. Sangar, **43**, 365
view of private owner in, Earl of Buckinghamshire, **43**, 365
Chlorophyll, Prof. R. P. Linstead, **43**, 359
CHRISTIAN, Dr. J. W., How metals transform, **43**, 359
CHRISTIE, J. T., The Ancient University, **43**, 365, **44**, 375
Chromosomes, and gene structure, **43**, 361
breakage consequences, Dr. J. McLeish, **43**, 361
molecular structure, Dr. E. J. Ambrose, **43**, 361
nucleic acid synthesis, Dr. J. M. Thoday, **43**, 361
Cine-camera, tool of science, Miss T. James, **43**, 365
CLARK, Prof. W. E. le Gros, Reason and fallacy in study of fossil man, **43**, 280
CLARKE, R. H., Whaling and stock of whales, **43**, 305, 360
CLAYTON, G., Provincial stock exchanges, **41**, 3
CLAYTON, R. W., Savannah landscapes, **43**, 361
CLIFFORD, Mrs. E. M., Caratacus in the Cotswold, **43**, 362
Climate and body shape, Dr. D. F. B. Roberts, **43**, 362
CLOUDSLEY-THOMPSON, Dr. J. L., Dispersal in some terrestrial arthropods, **41**, 73
CLOWES, Dr. F. A. L., Root apices, **43**, 364, 368
Coal and Britain's future, **43**, 359, 366, **44**, 441

Coal and chemical raw materials, Dr. R. Holroyd, **43**, 359
gasification of, Dr. F. J. Dent, **43**, 359
measures, Pembrokeshire, T. B. H. Jenkins, **43**, 360
processing, modern, Dr. W. Idris Jones, **43**, 359
Coalfield landscapes, national differences, T. H. Elkins, **43**, 361
Coast and the geographer, Prof. J. A. Steers, **42**, 171, **43**, 361
Coastal lands, protection of, J. Duvivier, **43**, 362
Coastal protection, W. V. Lewis, **43**, 362
COCKCROFT, Sir John, Recent developments in nuclear physics, **42**, 129, **43**, 359
COHEN, Prof. J., Conjecture and risk, **43**, 333, 363
COLE, Dr. Monica M., Growth of Witwatersrand conurbation, **43**, 361, 367
COLES, V. R., Problems of a practical forecaster, **43**, 359
COLLIS, Dr. Margaret M., Ecology of Sabellaria, **43**, 360
Colonial archaeology, Sir Mortimer Wheeler, **43**, 362
Colouring matters, complex, natural, **43**, 359
Communicable disease, natural history of, Prof. B. G. Maegraith, Prof. R. M. Gordon and Dr. R. B. Griffiths, Dr. A. R. D. Adams, Dr. W. H. Horner Andrews, Prof. T. H. Davey, Prof. A. W. Downie *et al.*, **41**, 87
Conditioned responses and the radar set, D. E. Broadbent, **43**, 364
Conifers, measuring of young, Dr. A. J. Rutter, **43**, 365
measurement in nursery, J. N. R. Jeffers, **43**, 365
Conjecture and risk, Prof. J. Cohen, **43**, 333, 363
Continental shelf, Dr. A. E. Moodie, **41**, 42
Convertibility, R. F. Harrod, **43**, 362
CONZEN, M. R. G., Urban morphology, **43**, 362
COOKE, Dr. A. H., Magnetism at low temperatures, **43**, 359
Co-operative field work, Dr. B. Campbell, **43**, 365
Corresponding Societies, Oxford Meeting, **43**, 304
Cortex, localisation of voluntary movement, Dr. J. A. V. Bates, **43**, 363
Cosmology, a physical science, Dr. T. Gold, **43**, 359
evolutionary processes, Dr. D. W. Sciama, **43**, 359
modern theories, Dr. H. Bondi, **43**, 359
COULSON, Prof. C. A., Science and religion, **43**, 321
Council's report to General Committee, 1953–4, **43**, 340
LA COUR, Dr. L. F., X-ray studies in endosperm, **43**, 361, 368
COURTIER, F., Grey squirrel populations, **43**, 364
Cow, the milking, A. S. Foot, **43**, 363
COX, Prof. E. G., Inorganic stereochemistry, **43**, 359, 366
Craftsmen, builders, architects: work in Oxford, E. M. Jope, **43**, 362
CRAIG, R. E., Echo-sounding, **41**, 51
CREER, Dr. K. M., Rock magnetism and polar wandering, **43**, 359
Criminological prediction tables, L. T. Wilkins, **43**, 363
CRISP, Dr. D. J., and SOUTHWARD, Dr. A. J., British marine fauna, **43**, 360, 367
CROMBIE, Dr. A. C., Oxford and history of science, **43**, 365
CROOKE, Dr. Myles, *Bupalus pinarius* L., **43**, 364
CROSS, Dr. B. A., Physiology of suckling and milking, **43**, 363, 368
CROWDEN, Prof. G. P., Habitability of dwellings, **43**, 363, 368, **44**, 411
Crustacea, moulting in, D. B. Carlisle, **43**, 361

DARLINGTON, Prof. C. D., Genetics and advancement of science, **43**, 361, 368
DAVEY, Prof. T. H., Medical policy and demographer, **41**, 95
Science and the unpredictable, **41**, 20
DAVIDSON, Miss M., Psychologist's findings, **43**, 364
Deaf people in hearing society, P. Gorman, **43**, 363
DENT, Dr. F. J., Gasification of coal, **43**, 359, **44**, 450
Derbyshire caves, report of a committee, **41**, 111
DICK, J. B., Effect of design on heating and ventilation of dwellings, **43**, 363, **44**, 422
DIMBLEBY, Dr. G. W., Ecological study of buried soils, **43**, 363
Heathland afforestation, **43**, 364
Discoveries from the air, Mediterranean, 1953–4, J. S. P. Bradford, **43**, 362
Disease in hot climates, research on, Prof. B. G. Maegraith, **41**, 87
DODD, Dr. J. M., Amphibian metamorphosis, **43**, 361
DOWNIE, Prof. A. W., DUMBELL, Dr. K. R., MCCARTHY, Dr. K., Infectivity of smallpox, **41**, 98
DOWNIE, C., Limestone bands in Kimmeridge clay, **43**, 360
Drawing operation, mechanism of, Prof. H. W. Swift, **43**, 362
DREVER, Dr. H. I., Origin of picrite, **43**, 360
Drug addiction, Dr. P. O. Wolff, **43**, 293, 363
Dual-fuel engine, J. R. Simonson, **43**, 362
DUNNING, J. H., N. American enterprise and British productivity, **43**, 362
DURY, Dr. G. H., Valleys, N.W. Oxford, **43**, 361, 367
DUVIVIER, J., Protection of coastal lands, **43**, 362, 367
Dwellings, effect of design on heating and ventilation, J. B. Dick, **43**, 363
habitability of, Prof. G. P. Crowden, **43**, 363

Echo-sounding, R. E. Craig, **41**, 51
Economy, changing structure of British, Prof. E. A. G. Robinson, **43**, 362
EDMONDS, J. M., Geology of Oxford, **43**, 360
John Phillips, **43**, 365
Education of women, Mrs. Mary Stocks, **43**, 365
Secondary, N. G. Fisher, **43**, 365
EGELSTAFF, P. A., Nuclear physics of thermal reactors, **43**, 359
Egyptian, Aegean and European archaeology, **43**, 362
Elasmobranch endocrine organs, C. K. Goddard, **43**, 361
Electricity production in Great Britain, geography of, E. M. Rawstron, **43**, 361
ELKINS, T. H., National differences in coalfield landscapes, **43**, 361
ELLIOTT, Dr. D. C., Glycollic acid and barley mechanism, **43**, 364
EMERY, Prof. W. B., Excavations, N. Sakkara, 1953–4, **43**, 362
Endosperm, X-ray studies, Dr. L. F. la Cour, **43**, 361
Engineer in management, Bosworth Monck, **43**, 362
Engineering progress and new materials, Dr. Willis Jackson, **42**, 194, **43**, 362
profession, recruitment to, **43**, 362, 367
English oral lore, P. Opie, **43**, 363
Entamoeba histolytica, pathogenicity, Dr. A. R. D. Adams, **41**, 91
Estate sawmills, Capt. G. C. Wolryche-Whitmore, **43**, 365
case against, Lt.-Col. A. V. Spencer, **43**, 365
Examination system, changes, J. F. Wolfenden, **43**, 365
history, G. Bruce, **43**, 365

Family or sibship position, J. P. Lees, **43**, 363
Farming, development of commercial, J. W. Y. Higgs, **43**, 365
Farms, political economy of, marginal, G. R. Allen, **43**, 365
Fat, deposition in farm animals, Dr. J. Hammond, **43**, 363
Fauna, British marine, Dr. D. J. Crisp and Dr. A. J. Southward, **43**, 360
Faunal provinces, British upper Domerian, D. V. Ager, **43**, 360
FELL, J. R., Grassland irrigation, **43**, 365
FERGUSON, Dr. J., Heavy chemical industries of Merseyside, **41**, 79
Ferns, leaf and bud primordia, Prof. C. W. Wardlaw, **43**, 364
Fieldwork in Ethiopia, Rev. G. Mathew, **43**, 362
Fifty years of external examinations, **43**, 365
Filarial infections, W. Africa, Prof. R. M. Gordon and Dr. W. E. Kershaw, **43**, 361
Filariasis, human, Prof. R. M. Gordon and Mr. R. B. Griffiths, **41**, 89
FINNISTON, Dr. H. M., Metallurgy and atomic enegry, **43**, 360
Firedamp, drainage, Dr. J. H. Jones, J. G. Bromilow, **43**, 362
Fish, direction finding in, Dr. H. W. Lissmann, **41**, 69
FISHER, N. G., Secondary education since 1945, **43**, 365, 368
Floods and coast erosion, **43**, 362, 367
Folk culture and folklore, **43**, 363
Folklore, collecting, P. Opie, **43**, 365
in twelfth century literature, Miss K.M. Briggs, **43**, 363
Food intake, central nervous control, Dr. G. C. Kennedy, **43**, 363
and obesity, Prof. J. Mayer, **43**, 363
FOOT, A. S., The milking cow, **43**, 363
FORD, Dr. E. B., Genetics and natural selection, **43**, 361
Forest economics and forest policy, W. E. Hiley, **43**, 312, 364
Forest trees and mineral nutrition, Dr. L. Leyton, **43**, 364
Forests, North American coastal, R. F. Wood, **43**, 365
Forecaster, problems of a practical, V. R. Coles, **43**, 359
Forecasting, medium and long range, Dr. J. M. Stagg, **43**, 359
numerical methods, Prof. C. G. Rossby **43**, 359
Fossil man, reason and fallacy in study of, Prof. W. E. Le Gros Clark, **43**, 280
Fossil reptiles, bone structure, Mrs. B. Hobson, **43**, 360
FRANKS, Dr. C. M., Mental abnormality and conditioned reflex, **43**, 364
FRASER, Dr. F. C., Cetaceans, **43**, 360, 367
Friction, Dr. F. P. Bowden, **43**, 265
Frontiers, opening up the new, Dr. P. V. Cardon, **43**, 365

GARRETT, Dr. S. D., Soil acidity and forest tree diseases, **43**, 364
GASCOIGNE, T., Biology of Limapontiidae, **43**, 360
GASKELL, Dr. T. F., Seismic measurements in Pacific, **41**, 61
Gene, desoxyribose nucleic acid nature, Dr. J. Chayen, **43**, 361
General Committee, Council's report to, 1953–4, **43**, 340
Genetics and advancement of science, Prof. C. D. Darlington, **43**, 361
and plant breeding, Prof. S. C. Harland, **43**, 361, **44**, 383
and medicine, Prof. L. S. Penrose, **43**, 361, **44**, 383
and physiology, Dr. D. Lewis, **43**, 361
and microbiology, Dr. G. Pontecorvo and Dr. J. A. Roper, **43**, 361
and taxonomy, Prof. J. Heslop Harrison, **43**, 361
and biometry, Prof. K. Mather, **43**, 361
and natural selection, Dr. E. B. Ford, **43**, 361
and animal breeding, Dr. A. Robertson, **43**, 361
Geological structures, trends of, Prof. O. T. Jones, **41**, 102
Geology of Oxford, J. M. Edmonds, **43**, 360

GEORGE, Prof. T. N., Limestones of Avonian S.W. province, **43**, 360
German refugees, 1945–53, R. E. M. Mellor, **43**, 361. **44**, 465
Germanium, applications, Dr. E. G. James, **43**, 360
Germanium and gallium, **43**, 366
A. R. Powell, **43**, 360
GILBERT, Prof. E. W., Oxford in geographical setting, **43**, 361
GLEES, Dr. F. P., and COLE, J., Sensorimotor skill in monkeys, **43**, 363
GLOVER, R. S., Science and herring fishery, **43**, 361, 367, **44**, 426
GODDARD, C. K., Elasmobranch endocrine organs, **43**, 361
GOLD, Dr. T., Cosmology as physical science, **43**, 359
Gold Coast, internal exchange of staple foods, H. P. White, **43**, 361
Golgi controversy, Dr. J. R. Baker, **43**, 360
GORDON, J. G., Appetite instinct, **43**, 361
GORDON, Prof. R. M., and Mr. R. B. Griffiths, Human filariasis, **41**, 89
and Dr. W. E. Kershaw, Filarial infections, W. Africa, **43**, 361
GORMAN, P., Deaf people in hearing society, **43**, 363, 368
GOULD, R., Teacher in twentieth century, **42**, 242, **43**, 365
GRACE, Dr. M. A., Radio-active decay, **43**, 359, 366
Grammar school, social changes, A. J. Lush, **43**, 365
Grassland irrigation, J. R. Fell, **43**, 365
Gravels in Reading area, Miss P. S. Walder and Dr. F. Hodson, **43**, 360
Gravity and magnetic anomalies in N. Wales, Dr. D. W. Powell, **41**, 110
Grey squirrel populations, F. Courtier, **43**, 364
GRIME, G., Vehicle design and road accidents, **43**, 362, 367
Growth and production, Prof. W. H. Pearsall, **42**, 232, **43**, 364
Growth versus choice, P. Wiles, **43**, 362
GUNN, D. C., Industrial steam generation, **43**, 362, 367
GUNTHER, Dr. Mavis, Clinical aspects of milk propulsion, **43**, 363

HALL, Dr. E. T., Spectroscopic analysis in archaeology, **43**, 363
Hallucinations, J. C. Raven, **43**, 364
HAMMOND, Dr. J., Deposition of fat in farm animals, **43**, 363
HARLAND, Prof. S. C., Genetics and plant breeding, **43**, 361, **44**, 383
HARLEY, Dr. J. L., Roots and micro-organisms, **43**, 364
HARRISON, Prof. J. Hislop, Genetics and taxonomy, **43**, 361, 368
HARROD, R. F., Convertibility, **43**, 362
HARVEY, D. W., Self-excited series transductor, **43**, 362, 367
HEARNSHAW, Prof. L. S., Psychology of thinking, **42**, 220, **43**, 363
Heathland afforestation, Dr. G. W. Dimbleby, **43**, 364
Heating and ventilation, physiology of, **43**, 363, 368, **44**, 409
Herbicides, Prof. G. E. Blackman, **43**, 365
Herring fishery, science and, R. S. Glover, **43**, 361, **44**, 426
populations, B. B. Parrish, **43**, 361
HIGGS, J. W. Y., Development of commercial farming, **43**, 365
Museum of Rural Life, Reading, **43**, 363
HILEY, W. E., Forest economics and forest policy, **43**, 312, 364
Hinchcliffe, O., Medical geography, **43**, 43, 362, 367
HINDE, Dr. R. A., Instinctive behaviour, **43**, 364, 368
HINSHELWOOD, Sir Cyril, Coal and Britain's future, **43**, 359
HOARE, E. R., Irrigation techniques, **43**, 365, 367
HOBSON, Mrs. B., Bone structure in fossil reptiles, **43**, 360
HOBSON, B. M., Reproduction in Anura, **43**, 361
HOLMES, Dr. W., Nervous system of amphioxus, **43**, 360, 367
HOLROYD, Dr. R., Coal as source of chemical raw materials, **43**, 359, 366, **44**, 454
Home, working conditions in, Dr. J. R. Brown, **43**, 363
HONEYMAN, A. M., Carboniferous oolites, S. Wales, **43**, 360
Hormones and zoological function, **43**, 361, 367
HOUSE, J. W., Rates of change in rural landscape, **43**, 361, 367
HUME-ROTHERY, Dr. W., Metals and alloys, **43**, 359
HUNTINGFORD, G. W. B., Archaeology in Ethiopia, **43**, 362

Immigrants, British, in W. Australia, A. Richardson, **43**, 363
INGOLD, Prof. C. K., Outlook in organic chemistry, **43**, 359
Insects, role of vision in, Dr. J. D. Carthy, **41**, 75
Instinctive behaviour, Dr. R. A. Hinde, **43**, 364
Intelligence test-scores, Dr. J. D. Nisbet, **41**, 13
Irrigation, need, Dr. H. L. Penman, **43**, 365
techniques, E. R. Hoare, **43**, 365

JACKSON, Dr. Willis, New materials and engineering progress, **42**, 194
Recruitment to engineering profession, **43**, 365
JAHODA, Dr. G., Attitudes to whites, **43**, 363
JAMES, Dr. E. G., Applications of Germanium, **43**, 360
JAMES, Miss T., Cine-camera, tool of science, **43**, 365
JAMES, Dr. W. O., Terminal oxidases of cereal seedlings, **43**, 273, 364
JEFFERS, J. N. R., Measurement of conifers in nursery, **43**, 365, 368
JENKINS, T. B. H., Correlation of Pembrokeshire coal measures, **43**, 360
JOHNSON, Dr. B. A., Behaviour syndromes, **43**, 363
JONES, Dr. J. H., and BROMILOW, J. G., Drainage of firedamp, **43**, 362, 367
JONES, Prof. O. T., Trends of geological structures, **41**, 102
JONES, Dr. W. Idris, Modern coal processing, **43**, 359, **44**, 441
JOPE, E. M., Craftsmen, builders and architects: work in Oxford, **43**, 362
Jurassic rocks, Sherborne-Burford, B. C. Worssam, **43**, 360

KAY, Dr. H. D., Physiology of milk liberation, **43**, 363
KENNA, Rev. V. E. G., Minoan seals, **43**, 362
KENNEDY, Dr. G. C., Central nervous control of food intake, **43**, 363
KESTEVEN, Dr. G. L., and Dr. K. V. L., Science and the unpredictable, **41**, 24, 28
Kimmeridge clay, limestone bands, C. Downie, **43**, 360
KING, G., Transistors, **43**, 362
KIRKALDY, Dr. J. F., Lower Cretaceous non-marine limestones, **43**, 360
KNIGHT, Prof. A. Rex, Animal and human behaviour, **43**, 364
Knowledge is power: or is it? Dr. W. F. Russell, **43**, 365
KNOWLES, K. G. J. C., Wage differentials, **43**, 362
KUENEN, Prof. Dr. Ph. H., Sedimentary rocks, interpretation of, **41**, 65
KURTI, Dr. N., Nuclear orientation at low temperature, **43**, 359, 366

LAMBERT, Dr. Audrey M., Oxfordshire, A.D. 1800, **43**, 361,
Landscape, rates of change in rural, J. W. House, **43**, 361
LANE, F. J., **43**, 367
LANE-PETTER, Dr. W., Science, animals and humanity, **43**, 361, 367
LANER, S., Visual aids and manipulative tasks, **43**, 364, 368
LAURIE, M. V., Acid soils and forest trees, **43**, 364
LAWSON, G. W., Intertidal zonation on Gold Coast, **43**, 364
Leaf formation, Dr. Robin Snow, Dr. Mary Snow, **43**, 364
LEES, J. P., Family or sibship position, **43**, 363, 368
LENNARD-JONES, Sir John, New ideas in chemistry, **42**, 136, **43**, 359
Leonardo da Vinci, Dr. F. Sherwood Taylor, **43**, 365, **44**, 435
Levant, irrigation projects, C. G. Smith, **43**, 362
LEWIS, Dr. D., Genetics and physiology, **43**, 361
LEWIS, W. V., Coastal protection, **43**, 362, 367
LEYTON, Dr. L., Mineral nutrition and forest trees, **43**, 364
LIDDELL, Prof. E. G. T., Brain and muscle, **43**, 363
Limapontiidae, biology, T. Gascoigne, **43**, 360
Limestone, the Durness, Dr. Vernon Wilson, **43**, 360
Limestones, Avonian S.W. province, Prof. T. N. George, **43**, 360
Lower Cretaceous, Dr. J. F. Kirkaldy, **43**, 360
their disposition and formation, **43**, 360
LINDSAY, D. D., Recruitment to engineering profession, **43**, 365
LINSTEAD, Prof. R. P., Chlorophyll, **43**, 359
LISSMAN, Dr. H. W., Direction finding in fish, **41**, 69
Low temperature physics, **43**, 359
research, Prof. Sir Francis E. Simon, **43**, 359
Lower Cretaceous palaeogeography, **43**, 360
LUSH, A. J., Social changes in grammar schools, **43**, 365
LYDALL, H. F., Changes in pattern of, **43**, 362

MACDONALD, Prof. A. D., Relief of pain, **42**, 212, **43**, 363
MACDONALD, J., Tree planting on coastal sands, **41**, 33
MAEGRAITH, Prof. B. G., Research into disease in hot climates, **41**, 87
Magnetisation in rocks, Dr. G. D. Nicholls, **43**, 359
Magnetism at low temperatures, Dr. A. H. Cooke, **43**, 359
Malaria, research projects, Dr. W. H. Horner Andrews, **41**, 93
MATHER, Prof. K., Genetics and biometry, **43**, 361
MATHEW, Rev. G., Fieldwork in Ethiopia, **43**, 362
MATTINGLY, P. F., Species hybrids in mosquitoes, **43**, 361
MAYER, Prof. J., Food intake and obesity, **43**, 363
McINNES, Dr. R. G., Psychiatric findings, **43**, 364
McLEISH, Dr. J., Consequences of chromosome breakage, **43**, 361
Medical geography, O. Hinchcliffe, **43**, 362
policy and demographer, Prof. T. H. Davey, **41**, 95
MEIKLEJOHN, Dr. A. P., Assessment of obesity, **43**, 363
Megalosaurus, Dr. W. E. Swinton, **43**, 360
MELLOR, R. E. H., German refugees, 1945–53, **43**, 361, **44**, 465
MENDELSSOHN, Dr. K., Superfluidity, **43**, 359
Mental abnormality and conditioned reflex, Dr. C. M. Franks, **43**, 364
Merseyside, heavy chemical industries, Dr. J. Ferguson, **41**, 79
Metallurgy and atomic energy, Dr. H. M. Finniston, **43**, 360
Metals and alloys, Dr. W. Hume-Rothery, **43**, how they transform, Dr. J. W. Christian, **43**, 359

Mice, and vole populations, H. N. Southern, **43**, 364
breeding below zero, Dr. S. A. Barnett, and Miss B. M. Manly, **43**, 361
MIDDLEMISS, F. A., Lower Cretaceous brachiopods, **43**, 360
Milk, liberation, physiology of, **43**, 363
propulsion, clinical aspects, Dr. Mavis Gunther, **43**, 363
MILLER, Prof. A. A., Mapping of strip lynchets, **43**, 277, 361
MILLER, A. D., Rehabilitation of broad-leaved woodlands, **43**, 365
Minoan seals, Rev. V. E. G. Kenna, **43**, 362
Minor element distribution in rocks, **43**, 360
Minor elements, Prof. J. F. Turner, **43**, 360
Miocene fauna, E. Africa, Dr. T. Whitworth, **43**, 360
Molecular dynamics and structure, Prof. E. Bright Wilson, **43**, 359
Mona complex in Lleyn, Sir Edward Bailey, **41**, 108
MONCK, Bosworth, Engineer in management, **43**, 362, 367
Monkeys, sensori-motor skill in, Dr. F. P. Glees and J. Cole, **43**, 363
MOODIE, Dr. A. E., Continental shelf, **41**, 42
Mor, formation of, Prof. L. G. Romell, **43**, 364
MORGAN, Dr. G. A. V., Verbal abilities, **43**, 364
Morphogenesis, **43**, 364
Morphology, urban, M. R. G. Conzen, **43**, 362
Mosquitoes, species hybrids, P. F. Mattingly, **43**, 361
Mouse chromosomes, Dr. B. M. Slizynksi, **43**, 361
MURRAY, G., Yieldpoint in steel, **43**, 362
Museum of English Rural Life, Reading, J. W. Y. Higgs, **43**, 363
Mycorrhiza, J. K. Brierley, **43**, 364
of beech, potassium uptake, J. M. Wilson, **43**, 364

Nerve cells, cytoplasmic inclusions, S. A. Shafiq, **43**, 360
NEUBERGER, Dr. A., Biogenesis of porphyrins, **43**, 359
Neurospora, mutations in, J. A. Pateman, **43**, 361
Neutron spectrometry, E. R. Wiblin, **43**, 359
NEWBERRY, C., Bird photography, **43**, 365
NICHOLLS, Dr. G. D., Magnetisation in rocks, **43**, 359
NICHOLSON, H. H., Prevention of waterlogging in soil, **43**, 365
NISBET, Dr. J. D., Intelligence test-scores, **41**, 13
NOCKOLDS, Dr. S. R., Trace elements in rock series, **43**, 360
North Sakkara, excavations, 1953–4, Prof. W. B. Emery, **43**, 362
Nuclear physics, Sir John Cockcroft, **42**, 129, **43**, 359
Nuclear orientation at low temperature, Dr. N. Kurti, **43**, 359
spins, determination of, Dr. B. Bleaney, **43**, 359

Oak, insect defoliators, Prof. G. C. Varley, **43**, 364
OAKLEY, Dr. K. P., Methods of dating bones, **43**, 363
Obesity, **43**, 363, 368
assessment of, Dr. A. P. Meiklejohn, **43**, 363, 368
Oolites, carboniferous, S. Wales, A. M. Honeyman, **43**, 360
OPIE, P., Collecting folklore, **43**, 365
English oral lore, **43**, 363, 368
ORWIN, Dr. C. S., Efficiency of medieval agriculture, **43**, 365, 369
Oxford, and history of Science, Dr. A. C. Crombie, **43**, 365
City, geographical setting, Prof. E. W. Gilbert, **43**, 361
Meeting, narrative of, **43**, 263
Sectional officers, **43**, 371
Sectional transactions, **43**, 359
Town planning, A. H. Smith, **43**, 362
Oxfordshire, A.D. 1800, Dr. Audrey M. Lambert, **43**, 361
Oxidases, of cereal seedlings, Dr. W. O. James, **43**, 273, 364

Pain, relief of, Prof. A. D. Macdonald, **42**, 212
Palaeography, Lower Cretaceous, **43**, 360
Palaeontology, and stratigraphy, Dr. C. J. Stubblefield, **42**, 149, **43**, 360
vertebrate, **43**, 360
Paper-mills, early, in England, A. H. Shorter, **43**, 361
PARKER, Dr. A., House heating and atmospheric pollution, **43**, 363, **44**, 418
PARNELL, Dr. R. W., Physique and traits, **43**, 364
PARRISH, B. B., Herring populations, **43**, 361
PATEMAN, J. A., Mutations in neurospora, **43**, 361
PEARSALL, Prof. W. H., Growth and production, **42**, 232, **43**, 364
Peltigera polydactyla, sugar uptake, D. C. Smith, **43**, 364
PENMAN, Dr. H. L., Irrigation need, **43**, 365
PENNYBACKER, J. B., Surgery and relief of pain, **43**, 298, 363
PENROSE, Prof. L. S., Genetics and medicine, **43**, 361, **44**, 383
Personality and culture pattern, Dr. Martha Vidor, **43**, 363
traits in 7-year-old children, **43**, 364
Phenology—study of seasons, Dr. C. B. Williams, **43**, 267, 365
PHILLIPS, John, Professor of Geology, Oxford (1854–74), J. M. Edmonds, **43**, 365
Photographic composition of reading matter, G. Westover, **43**, 362
Phylogeny, P. Bell, **43**, 364
Physics, low temperature, **43**, 359
nuclear, **43**, 359
of weather forecasting, Dr. R. C. Sutcliffe, **43**, 359
Physique and traits, Dr. R. W. Parnell, **43**, 364
Picrite, origin of, Dr. H. I. Drever, **43**, 360
Pink-footed goose, population study, Peter Scott, **43**, 365
Plant respiration, Dr. J. Barker and Dr. L. W. Mapson, **43**, 364
PONTECORVO, Dr. G., and ROPER, Dr. J. A., Genetics and microbiology, **43**, 361
Population, variation in age and sex structure, 1931 and 1951, Dr. M. J. Wise and D. J. Sinclair, **43**, 361
Porphyrins, biogenesis of, Dr. A. Neuberger, **43**, 359
POWELL, A. R., Germanium and gallium, **43**, 360, 366
POWELL, Dr. D. W., Gravity and magnetic anomalies in North Wales, **41**, 110
Productivity, British, and N. American enterprise, J. H. Dunning, **43**, 362
Protoplasm, electron microscope studies, Dr. J. R. G. Bradfield, **43**, 360
Psammites du Condroz, sedimentology of, Dr. L. M. J. U. van Straaten, **41**, 66
Psychiatric findings, Dr. R. G. McInnes, **43**, 364
Psychologist's findings, Miss M. Davidson, **43**, 364
Psychology, and other disciplines, Prof. F. V. Smith, **43**, 364
and public, Prof. C. W. Valentine, **43**, 363
of thinking, Prof. L. S. Hearnshaw, **43**, 220, **43**, 363
Publication, references to, Oxford meeting **43**, 366

Radio-active decay, Dr. M. A. Grace, **43**, 359
RAVEN, J. C., Hallucinations, **43**, 364
RAWLINS, F. I. G., Science and museum objects, **43**, 365
RAWSTRON, E. M., Electricity production in Great Britain, geography of, **43**, 361, 367
Recruitment to engineering profession, Dr. Willis Jackson, D. D. Lindsay, H. A. Warren, **43**, 365
Relief of pain, Prof. A. D. Macdonald, **43**, 363
Dr. P. O. Wolff, J. B. Pennybacker, **43**, 293, 298
Research committees, 1954–5, **43**, 370
RICHARDSON, A., British immigrants in W. Australia, **43**, 363
RIDE, W. D. L., Fossil marsupials, Burramy's *Broom*, **43**, 360
DU RIETZ, Prof. G. E., Swedish mountain vegetation, **43**, 364
RITCHIE, Miss A. F., Alcohol formation in plants, **43**, 364
Road accidents and vehicle design, G. Grime, **43**, 362
ROBERTS, Dr. D. F. B., Climate and body shape, **43**, 362
ROBERTSON, Dr. A., Genetics and animal breeding, **43**, 361
ROBINSON, Prof. E. A. G., Changing structure of British economy, **42**, 182, **43**, 362
Rock magnetism, Prof. P. M. S. Blackett, **43**, 359
and polar wandering, Dr. K. M. Creer, **43**, 359
Series, trace elements in, Dr. S. R. Nockolds, **43**, 360
Rocks, and meteorites, elements in, Dr. L. H. Ahrens, **43**, 360
magnetisation, Dr. G. D. Nicholls, **43**, 359
magnetism of, **43**, 359
minor element distribution in, **43**, 360
ROMELL, Prof. L. G., Formation of Mor, **43**, 364
Root apices, Dr. F. A. L. Clowes, **43**, 364
Roots and micro-organisms, Dr. J. L. Harley, **43**, 364
ROSE, G. N., Distribution of zircon, **43**, 360
ROSENHEAD, Prof. L., Science and the unpredictable, **41**, 17
ROSSBY, Prof. C. G., Numerical forecasting, methods, **43**, 359
RUNCORN, Dr. S. K., and CREER, Dr. K. M., **43**, 366
RUSSELL, Dr. W. F., Knowledge is power: or is it?, **43**, 365
RUTTER, Dr. A. J., Measuring young conifers, **43**, 365

Sabellaria, ecology of, Dr. Margaret M. Collis, **43**, 360
Sand dunes, afforestation of, J. Macdonald, P. Thaarup, **41**, 33
SANGAR, D. J., Chilterns project, **43**, 365
Savannah landscapes, R. W. Clayton, **43**, 361
Saving, changes in pattern of, H. F. Lydall, **43**, 362
Schools and the community, **43**, 365
SCIAMA, Dr. D. W., Evolutionary processes in cosmology, **43**, 359
Science animals and humanity, Dr. W. Lane-Petter, **43**, 361
and the herring fishery, **43**, 361, **44**, 426
and human nature, Dr. E. D. Adrian, **42**, 121
and industry, case studies, Prof. B. R. Williams, **43**, 362
Committee, Prof. C. F. Carter, **43**, 362, **44**, 404
and museum objects, F. I. G. Rawlins, **43**, 365
and religion, Prof. C. A. Coulson, **43**, 321
and the unpredictable, Prof. L. Rosenhead, etc., **41**, 17
SCOTT, Peter, Pink-footed goose population study, **43**, 365
Sea-floor, photography of, Dr. H. G. Vevers, **41**, 49
Sectional officers, Oxford meeting, **43**, 371
transactions, Oxford, **43**, 359
Sedimentary rocks, Prof. Dr. Ph. H. Kuenen, Dr. L. M. J. U. van Straaten, **41**, 65
trace elements, Dr. J. R. Butler, **43**, 360

Seismic measurements in Pacific, Dr. T. F. Gaskell, **41**, 61
Seismological investigations, report of a committee, **41**, 112, **43**, 355
Semi-conductors, Dr. R. A. Smith, **43**, 359, **44**, 391
Sewage, farms and birds, W. B. Alexander, **43**, 361
filters, insect population, T. G. Tomlinson, **43**, 361
treatment, biological problems, Prof. E. A. Spaul, **43**, 361
Sewer rat populations, Dr. E. W. Bentley, **43**, 361
SHACKLETON, Prof. R. M., Structure and succession in Anglesey, **41**, 106
SHAFIQ, S. A., Cytoplasmic inclusions in nerve cells, **43**, 360, 367
SHORTER, A. H., Early paper-mills in England, **43**, 361
Significance test of, G. Spencer Brown, **43**, 363
SILVERMAN, P. H., Survival of egg of beef tapeworm, **43**, 361
SIMON, Prof. Sir Francis E., Low temperature research, **43**, 359
SIMONSON, J. R., Dual-fuel engine, **43**, 362
Site potentiality, J. M. B. Brown, **43**, 365
SLADE, Dr. R. E., Agriculture, the industry and the science, **42**, 251, **43**, 365
Slieve Gullion, Sir Edward Bailey and Prof. W. J. McCallien, **43**, 360
SLIZYNSKI, Dr. B. M., Mouse chromosomes, **43**, 361
SMALES, A. A., Analytical problems, **43**, 360, 366
Smallpox, infectivity of, Prof. A. W. Downie, Dr. K. R. Dumbell, Dr. K. McCarthy, **41**, 98
SMITH, A. H., Town planning of Oxford, **43**, 362
SMITH, C. G., Irrigation projects, Levant, **43**, 362
SMITH, D. C., Sugar uptake by *Peltigera polydactyla*, **43**, 364
SMITH, Prof. F. V., Psychology and other disciplines, **43**, 364
SMITH, Dr. R. A., Semi-conductors, **43**, 359, 366, **44**, 391
SNOW, Dr. Robin and Dr. Mary, Leaf formation, **43**, 364
Soil acidity and forest tree disease, Dr. S. D. Garrett, **43**, 364
Soils, ecological study, of buried, Dr. G. W. Dimbleby, **43**, 363
SOUTHERN, H. N., Mice and vole populations, **43**, 364
SPAUL, Prof. E. A., Biological problems of sewage treatment, **43**, 361
Speech and handedness, Prof. O. L. Zangwill, **43**, 363
SPENCER, Lt.-Col. A. V., Case against estate saw mills, **43**, 365, 368
STAGG, Dr. J. M., Medium and long range forecasting, **43**, 359, 366
Statistics of parapsychology, **43**, 363
Statistical significance and parapsychology, Dr. G. D. Wassermann, **43**, 363
theory, Dr. R. H. Thouless, **43**, 363
Steam generation, industrial, D. C. Gunn, **43**, 362
Stereochemistry, inorganic, Prof. E. G. Cox, **43**, 359
Steel, yield point, G. Murray, **43**, 362
STEERS, Prof. J. A., Coast and the geographer, **42**, 171, **43**, 361
STEWART, Prof. W. A. C., The modern university, **43**, 365
Stock exchanges, provincial, G. Clayton, **41**, 3
STOCKS, Mrs. M., Education of women, **43**, 365
Strip lynchets, mapping of, Prof. A. A. Miller, **43**, 277, 361
STUBBLEFIELD, Dr. C. J., Palaeontology and stratigraphy, **42**, 149, **43**, 360
Suckling and milking, physiology, Dr. B. A. Cross, **43**, 363
Superfluidity, Dr. K. Mendelssohn, **43**, 359
Surgery and relief of pain, J. B. Pennybacker, **43**, 298, 363
SUTCLIFFE, Dr. R. C., Weather forecasting and physics, **43**, 359, 366
SWANN, Prof. M. M., What makes a cell divide?, **43**, 360, 367
Swedish mountain vegetation, Prof. G. E. du Rietz, **43**, 364
SWEETING, Dr. Marjorie M., and GROOM, Miss G. E., Physiography of Bünsowland, **43**, 361, 367
SWIFT, Prof. H. W., Mechanism of drawing operation, **43**, 362, 367
SWINTON, Dr. W. E. Megalosaurus, **43**, 360

Talerddig district, folds and cleavage, Dr. D. A. Bassett, **41**, 108
Talitrus saltator, Dr. D. I. Williamson, **41**, 71
TANNER, Dr. J. M., Body form in man, **43**, 363
TAYLOR, Dr. F. Sherwood, Leonardo da Vinci, **43**, 365, 369, **44**, 435
Teacher in twentieth century, Ronald Gould, **42**, 242, **43**, 365
Television, underwater and marine research, Dr. H. Barnes, **41**, 55
Textile industry, Oxfordshire, Dr. R. P. Beckinsale, **43**, 361
THAARUP, P., Afforestation of sand-dunes in Denmark, **41** 38
Thermal reactors, nuclear physics of, P. A. Egelstaff, **43**, 359
Thinking, psychology of, Prof. L. S. Hearnshaw, **42**, 220
THODAY, Dr. J. M., Nucleic acid synthesis and chromosomes, **43**, 361, 369
THOMAS, N., Beaker period sites, **43**, 362
THOMAS, Prof. P. T., The centromere, **43**, 361
THOMPSON, G. H., Animal populations and forestry, **43**, 364, 369
THOULESS, Dr. R. H., Statistical theory, **43**, 363
Thyroid and evolution, Prof. E. J. W. Barrington, **43**, 361
TINBERGEN, Dr. N., Animal behaviour, **43**, 363, 365
TODD, Prof. A. R., Colouring matters of aphids, **43**, 359
TOMLINSON, T. G., and HAWKES, H. A., Insect population of sewage filters, **43**, 361
Transductor, self-excited series, D. W. Harvey, **43**, 362
Transistors, G. King, **43**, 362
Treasurer's statement and account, 1953–1954, **43**, 347
TURNER, Prof. J. F., Minor elements, **43**, 360
TWISELTON, G. R., Psychological factors in child neglect, **43**, 363

Underwater films, W. D. Chesterman, **41**, 54
Underwater observations, Dr. H. G. Vevers, R. E. Craig, W. D. Chesterman, Dr. H. Barnes, Dr. T. F. Gaskell, **41**, 49
UNDERWOOD, G., Study of reptilian visual cells, **43**, 360
University, adaptation to community, **43**, 365
The Ancient, J. T. Christie, **43**, 365, **44**, 375
The Modern, Prof. W. A. C. Stewart, **43**, 365

VALENTINE, Prof. C. W., Psychology and the public, **43**, 363
Valleys, N.W. Oxford, Dr. G. H. Drury, **43**, 361
VAN STRAATEN, Dr. L. M. J. U., Sedimentology of the Psammites du Condroz, **41**, 66
VARLEY, Prof. G. C., Insect defoliators of oak, **43**, 364
Vehicle, and road safety, **43**, 367
design and safety, D. Bastow, **43**, 362
VENESS, Miss T., Ambitiousness among school-leavers, **43**, 364
Verbal abilities, Dr. G. A. V. Morgan, **43**, 364
VEVERS, Dr. H. G., Photography of sea floor, **41**, 49
VIDOR, Dr. Martha, Personality and culture pattern, **43**, 363
Visual aids, and manipulative tasks, S. Laner, **43**, 364

Wage differentials, K. G. J. C. Knowles, **43**, 362
WAIDE, J. S., Root surface fungi in the beech, **43**, 364
WAINWRIGHT, Dr. F. T., ninth and tenth century burhs, Mercia and Wessex, **43**, 362
WALDER, Miss P. S., HODSON, Dr. F., Gravels in Reading area, **43**, 360
Wales, structure of North and Central, Prof. O. T. Jones, Prof. R. M. Shackleton, Dr. D. A. Bassett, Dr. D. A. Powell, **41**, 102
WARDLAW, Prof. C. W., Leaf and bud primordia in ferns, **43**, 364
WARREN, H. A., Recruitment to engineering profession, **43**, 365, 369
WASSERMAN, Dr. G. D., Statistical significance and parapsychology, **43**, 363
Water control and crop production, **43**, 365
Waterlogging in soil, prevention, H. H. Nicholson, **43**, 365
WATSON, Dr. E. V., Bryophyte communities, **43**, 364
Weather forecasting, **43**, 359, 366
WEINER, Dr. J. S., Physical anthropology, **43**, 363, 368
WESTOVER, G., Photographic composition of reading matter, **43**, 362, 367
Whale-marking, S. G. Brown, **43**, 360
Whaling and stock of whales, R. Clarke, **43**, 305, 360
What makes a cell divide?, Prof. M. M. Swann, **43**, 360
WHEELER, Sir Mortimer, Colonial archaeology, **42**, 203, **43**, 362
WHITE, H. P., Internal exchange staple foods, Gold Coast, **43**, 361
WHITEHEAD, Dr. F. H., Alpine communities and growth form, **43**, 364
Whites, attitudes to, Dr. G. Jahoda, **43**, 363
WHITWORTH, Dr. T., E. African miocene fauna, **43**, 360
WIBLIN, E. R., Neutron spectrometry, **43**, 359
WILKINS, L. T., Criminological prediction tables, **43**, 363
WILES, P., Growth versus choice, **43**, 362
WILLIAMS, Prof. B. R., Case studies, science and industry, **43**, 362
WILLIAMS, Dr. C. B., Phenology—study of seasons, **43**, 267, 365
WILLIAMSON, Dr. D. I., Talitrus saltator, **41**, 71
WILSON, Prof. E. Bright, Molecular dynamics and structure, **43**, 359
WILSON, J. M., Potassium uptake by mycorrhiza of beech, **43**, 364
WILSON, Dr. Vernon, The Durness limestone, **43**, 360
WISE, Dr. M. J., and SINCLAIR, D. J., Variation in age and sex structure, 1931, 1951, **43**, 361
Witwatersrand, growth of a conurbation, Dr. Monica M. Cole, **43**, 367
WOLFENDEN, J. F., Examination system, changes, **43**, 365
WOLFF, Dr. P. O., Relief of pain—general views on drug addiction, **43**, 293, 363
WOLRYCHE-WHITMORE, Capt. G. C., Estate sawmills, **43**, 365
WOOD, R. F., N. American coastal forests, **43**, 365
Woodlands, rehabilitation of broad-leaved, A. D. Miller, **43**, 365
WORSSAM, B. C., Jurassic rocks, Sherborne-Burford, **43**, 360

ZANGWILL, Prof. O. L., Speech and handedness, **43**, 363, 368
Zircon, distribution, G. N. Rose, **43**, 360
Zonation, Intertidal, on Gold Coast, G. W. Lawson, **43**, 364
Zoology of sewers, **43**, 361

Printed in Great Britain by Spottiswoode, Ballantyne & Co. Ltd., London and Colchester

A QUARTERLY PUBLICATION ISSUED FREE No. 8

INFORMATION

BEING A LIST OF

SCIENTIFIC ARTICLES

Published in the following Journals during the months of

OCTOBER - NOVEMBER - DECEMBER 1954

ATOMIC SCIENTISTS' JOURNAL

THE PHILOSOPHICAL MAGAZINE

ADVANCES IN PHYSICS

ANNALS OF SCIENCE

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY
PROCEEDINGS OF THE ROYAL SOCIETY

THE JOURNAL OF THE QUEKETT MICROSCOPICAL CLUB

PROCEEDINGS OF THE PHYSICAL SOCIETY
REPORTS ON PROGRESS IN PHYSICS

ROYAL ASTRONOMICAL SOCIETY :
- MONTHLY NOTICES
- GEOPHYSICAL SUPPLEMENT
- OCCASIONAL NOTES
- MEMOIRS OF THE ROYAL ASTRONOMICAL SOCIETY

ANNALS & MAGAZINE OF NATURAL HISTORY

TAYLOR & FRANCIS LTD.

RED LION COURT, FLEET STREET, LONDON, E.C.4

DAWSON REPRINTS

INTERNATIONAL JOURNAL OF PSYCHO-ANALYSIS

Journal of the Psycho-Analytical Society. (Founded 1919.) Volumes 1-30, 1920-1950. Bound.

Set £150. 0. 0. Separate volumes *pro rata.*

This is perhaps the most important addition to reprinted periodical literature in recent years. Place your order immediately. First volumes ready soon.

JOURNAL OF PHYSIOLOGY

Journal of the Physiological Society. (Founded 1876.) Volumes 1-25, 1876-1900.

Set £150. 0. 0. Bound.

The Physiological Society was founded largely as a dining club whose meetings were preceded by scientific demonstrations and communications. In spite of the difficulties created by the considerable increase in membership, attempts have been made to preserve some of the informality and close acquaintanceship which usually characterizes a dining club. Members of the Society must be or have been actively engaged in physiological research or teaching. The Society numbers professional biochemists, anatomists, zoologists, pathologists, and clinicians among its members.

We hold all publishers' stock of this Journal up to Volume 60. Some odd parts and volumes still remain. Volumes 26–50 will be reprinted, should demand be sufficient.

WM DAWSON & SONS, LTD 102 Wigmore St., London, W.1.

Printed and Published by Taylor & Francis, Ltd.

ATOMIC SCIENTISTS' JOURNAL

The Official Publication of the Atomic Scientists' Association

The *Journal* contains articles by acknowledged authorities on various aspects of atomic energy, and provides a medium in which atomic scientists can discuss their work and its wider implications. It also provides a channel of communication between the specialists and the general public. Published every two months.

Ann. Sub. £1 12 6, *post free* **6/- per part,** *plus postage*

SEPTEMBER 1954

Symposium on the Morality of Atomic Warfare. By The Archbishop of York, Very Rev. Paul Foster, O.P., Prof. C. A. Coulson, F.R.S., Prof. K. Lonsdale, F.R.S., Prof. R. E. Peierls, F.R.S., Prof. H. W. B. Skinner, F.R.S., Marshal of the R.A.F. Sir John Slessor, Prof. Sir George Thomson, F.R.S. and Mr. G. N. Walton.

Editorial.

Symposium on the Morality of Atomic Warfare.

Annual General Meeting.

London Branch Meetings on Atomic Energy.

News Review. By A. G. Hester.

Book Review. By Dr. P. E. Hodgson.

Articles Relevant to the Moral Issues of Atomic Energy previously published in the *Atomic Scientists' News* **and the** *Atomic Scientists' Journal.* By G. N. Walton.

NOVEMBER 1954

Editorial.

A Chronology of the Negotiations for the International Control of Atomic Energy. Prof. K. Lonsdale.

The International Control of Atomic Energy. Dr. P. E. Hodgson.

Bikini Ash. Prof. Y. Nishiwaki.

News Review. By A. G. Hester.

Book Reviews. By Dr. W. Weinstein and Dr. P. E. Hodgson.

JANUARY 1955

Editorial.

In the Matter of J. Robert Oppenheimer. By Prof. R. E. Peierls.

The "Atomic" Rivals. By Sir Francis Simon.

Statement of the Science Council of Japan.

Atomic Physics in Australia, 1954. By Dr. P. Swan.

News Review. By A. G. Hester.

Book Reviews. By Sir George Thomson, F.R.S., A. W. Merrison and M. J. Moore.

Obituary of Professor Fermi. By Prof. R. E. Peierls.

(Subject to alteration up to the time of going to Press)

THE PHILOSOPHICAL MAGAZINE

A Journal of Theoretical, Experimental and Applied Physics

The *Philosophical Magazine* is an independently owned journal for the publication of papers in Natural Philosophy; under this term the Editors include experimental and theoretical physics, theoretical mechanics and certain branches of applied mathematics. This important monthly publication has been published continuously since 1798.

Ann. Sub. £8 0 0, *post free* **15/- per part,** *plus postage*

OCTOBER 1954

An Experimental Investigation of the Interaction of a Shock Wave with a Subsonic Stream Bounded by a Wall. By D. W. HOLDER, A. CHINNECK and G. E. GADD, Aerodynamics Division, National Physical Laboratory.

Astrophysical Considerations Regarding Freundlich's Red-Shift. By W. H. MCCREA, Royal Holloway College.

On the Observational Data Relating to Freundlich's Proposed Red-Shift Law. By E. MARGARET BURBIDGE, Cambridge and G. R. BURBIDGE, Cavendish Laboratory, Cambridge.

Some more Remarks on Freundlich's Red-Shift. By D. TER HAAR, St. Salvator's College, University of St. Andrews.

Measurements of Forty-four Charged V-Events. By J. S. BUCHANAN, W. A. COOPER, D. D. MILLAR and J. A. NEWTH, The Physical Laboratories, The University, Manchester.

Evidence for the β-Decay of a K-Meson. By M. W. FRIEDLANDER, D. KEEFE, M. G. K. MENON and L. VAN ROSSUM, H. H. Wills Physical Laboratory, University of Bristol.

Counters with Random Dead Time. By ALLADI RAMAKRISHNAN, Department of Physics, University of Madras.

On the Molecular Distribution Functions of a One-Dimensional Fluid: II. By ALLADI RAMAKRISHNAN and P. M. MATHEWS, Department of Physics, University of Madras.

A Cloud Chamber Study of the Interactions of Fast μ-Mesons. By V. APPAPILLAI, A. W. MAILVAGANAM and A. W. WOLFENDALE, The Physical Laboratories, University of Ceylon.

Notes on Soft X-ray Spectra, particularly of the Fe Group Elements. By H. W. B. SKINNER, F.R.S., T. G. BULLEN and J. E. JOHNSTON, The University, Liverpool.

Correspondence :—

The Mechanism of Rolling Friction. By D. TABOR, Research Laboratory for the Physics and Chemistry of Surfaces, Department of Physical Chemistry, Cambridge.

The Thickness of the Saturated Helium Film Above and Below the λ-point. By A. C. HAM and L. C. JACKSON, H. H. Wills Physical Laboratory, University of Bristol.

Electrical Resistance Minimum in Dilute Copper Alloys. By W. B. PEARSON, Division of Physics, National Research Council, Ottawa, Canada.

A 7-Second Iridium Isomer. By F. D. S. BUTEMENT and A. J. POË, Atomic Energy Research Establishment, Harwell.

The Philosophical Magazine (*continued*)

The Scattering of Deuterons and Protons by Alpha-Particles. By R. G. FREEMANTLE, Physics Department, University of Birmingham, T. GROTDAL, Fysisk Institutt, University of Bergen, Norway, W. M. GIBSON, R. MCKEAGUE, Physics Department, Queen's University of Belfast, D. J. PROWSE, H. H. Wills Physical Laboratory, University of Bristol and J. ROTBLAT, Physics Department, St. Bartholomew's Hospital, London.

Polytypism of Cadmium Iodide. By RICHARD S. MITCHELL, Department of Geology, University of Virginia, Charlottesville, Virginia.

Direct Evidence for Dislocations in Aluminium–Copper Alloys. By HEINZ WILSDORF, National Physical Laboratory, South African Council for Scientific and Industrial Research, Pretoria and DORIS KUHLMANN-WILSDORF, Department of Physics, University of the Witwatersrand, Johannesburg.

Notices of New Books and Periodicals Received.

NOVEMBER 1954

A Search for National Radioactivity in Neodymium, Rhenium and Osmium. By D. DIXON and A. MCNAIR, Department of Natural Philosophy, University of Glasgow.

Time Variations of Extensive Air Showers and the Origin of Cosmic Rays. By T. E. CRANSHAW and W. GALBRAITH, Atomic Energy Research Establishment, Harwell.

Statistics of the Occupation of Dislocation Acceptor Centres. By W. T. READ, Jr., Bell Telephone Laboratories, N.J.

A Restricted Quantum Statistical Proof of the Third Law of Thermodynamics. By P. T. LANDSBERG, Randal Morgan Laboratory, University of Pennsylvania, Philadelphia.

The Isotropic Component of Cosmic Radio-Frequency Radiation. By J. R. SHAKESHAFT, Cavendish Laboratory, Cambridge.

Double Pion Production and the Nature of Pseudoscalar Coupling. By P. BOCCHIERI and G. FELDMAN, Department of Mathematical Physics, The University, Birmingham.

An Elementary Reasoned Account of the General Circulation of the Atmosphere. By M. J. LIGHTHILL, Department of Mathematics, University of Manchester.

The Specific Heat of Liquid Helium II as a Function of Pressure. By G. R. HERCUS and J. WILKS, Clarendon Laboratory, Oxford.

The Surface Energy of Sodium. By ALLEN B. SCOTT, H. H. Wills Physical Laboratory, University of Bristol.

On the Inhibition of Convection by a Magnetic Field : II. By S. CHANDRASEKHAR, F.R.S., Yerkes Observatory, University of Chicago.

Nuclear Orientation of ^{54}Mn. By M. A. GRACE, C. E. JOHNSON, N. KURTI, H. R. LEMMER and F. N. H. ROBINSON, Clarendon Laboratory, Oxford.

Polarized γ-Rays from Oriented ^{54}Mn Nuclei. By G. R. BISHOP, J. M. DANIELS, H. DURAND, C. E. JOHNSON and J. PEREZ, Clarendon Laboratory, Oxford.

Interaction of 19 MeV Deuterons with Carbon. By R. G. FREEMANTLE, University of Birmingham, W. M. GIBSON, The Queen's University of Belfast and J. ROTBLAT, St. Bartholomew's Hospital Medical College, London.

Angular Distribution of Neutrons from the Reaction ^{11}B(d, n)^{12}C at 0·85 MeV Bombarding Energy. By ARNFINN GRAUE, Fysisk Institutt, Norway.

The Philosophical Magazine (*continued*)

Correspondence :—

On the Acceleration of Cosmic Ray Particles. By W. B. THOMPSON, Atomic Energy Research Establishment, Harwell.

On the Evaluation of Characteristic Temperatures for Cubic Crystals. By A. B. BHATIA and G. E. TAUBER, Division of Physics, National Research Council, Ottawa.

The Elastic Scattering of Protons by Fluorine. By G. DEARNALEY, Cavendish Laboratory, Cambridge.

On the Interaction of a Dislocation and a Charged Solute Ion. By ROLF LANDAUER, Research Department, International Business Machines Corporation, Poughkeepsie, New York.

Further Evidence for the β-Decay of K-Mesons. By C. DAHANAYAKE, P. E. FRANCOIS, Y. FUJIMOTO, P. IREDALE, C. J. WADDINGTON and M. YASIN, H. H. Wills Physical Laboratory, University of Bristol.

Paramagnetic Resonance at Radio Frequencies in Low Temperature Carbons. By D. J. E. INGRAM and J. G. TAPLEY, Department of Electronics, University of Southampton.

Notices of New Books and Periodicals received.

DECEMBER 1954

Concentration Contours in Grain Boundary Diffusion. By R. T. P. WHIPPLE, Atomic Energy Research Establishment, Harwell, Berks.

The Physical Nature of a Metal Surface in Conduction Theory. By H. A. MÜSER, British Council Fellow at H. H. Wills Physical Laboratory, University of Bristol.

Turbulence in the Upper Ionosphere. By A. MAXWELL, Jodrell Bank Experimental Station, University of Manchester.

Self Trapped Electrons in a Fermi Gas. By J. S. PLASKETT, H. H. Wills Physical Laboratory, University of Bristol.

Boundary Layer Growth in Three Dimensions. By L. C. SQUIRE, Department of Mathematics, University of Bristol.

Delayed Disintegration of a Nuclear Fragment. By A. SOLHEIM and S. O. SÖRENSEN, Fysisk Institutt, University of Oslo, Norway.

A Cloud Chamber Study of Cosmic Ray Interactions Underground. By H. J. J. BRADDICK and B. LEONTIC, The Physical Laboratories, The University of Manchester.

The Quasi-Cylindrical Shock Tube. By W. CHESTER, Department of Mathematics, University of Bristol.

Multiple Beam Investigation of Liquid Helium in Narrow Gaps. By N. G. MCCRUM, Clarendon Laboratory, Oxford.

The Alpha-Particle Component of the Cosmic Radiation. By C. J. WADDINGTON, H. H. Wills Physical Laboratory, University of Bristol.

Neutron-Widths and the Density of Nuclear Levels. By J. M. C. SCOTT, Cavendish Laboratory.

The Characteristic Temperature of Platinum from X-ray Reflections. By K. ALEXOPOULOS and P. EUTHYMIOU, Physical Laboratory, University of Athens.

Correspondence :—

The Lattice Thermal Conductivity of Dilute Copper Alloys at Low Temperatures. By G. K. WHITE and S. B. WOODS, Division of Physics, National Research Council, Ottawa, Canada.

Notices of New Books and Periodicals received.

Index to Volume.

Printed and Published by Taylor & Francis, Ltd. 5

ADVANCES IN PHYSICS

A Quarterly Supplement of the Philosophical Magazine

On 1st January 1952 the *Philosophical Magazine* published the first number of a new quarterly supplement. The aim of this supplement will be to give those interested in physics comprehensive and authoritative accounts of recent important developments. It is felt by the Editor that, in view of the rapid advances in many branches of physics, scientists will welcome a journal devoted to articles of this type.

Ann. Sub. £2 15 0, *post free* **15/- per part,** *plus postage*

NUMBER 12—OCTOBER 1954

Twinned Crystals. By R. W. CAHN, The Johns Hopkins University, Maryland, U.S.A.

Electronic Structure of Primary Solid Solutions in Metals. By J. FRIEDEL, Centre de Recherches Metallurgiques de l'Ecole des Mines de Paris, France.

NUMBER 13—JANUARY 1955

Antiferromagnetism. By T. NAGAMIYA, K. YOSIDA, Department of Physics, Osaka University, and R. KUBO, Department of Physics, Tokyo University.

Introduction.

Part I. **Fundamental Facts and Elementary Theory.**

Part II. **Indirect Exchange Interaction and Anisotropy Energy.**

Part III. **Statistical Theory of Antiferromagnetism.**

Early Scientific Publications

DIARY OF ROBERT HOOKE, M.A., M.D., F.R.S.
1672-1680

Edited by **H. W. ROBINSON** and **W. ADAMS**
Recommended for publication by the Royal Society, London

25/- net

"This vivid record of the scientific, artistic and social activities of a remarkable man during remarkable years has too long remained in obscurity."—Extract from foreword by Sir Frederick Gowland Hopkins, O.M., President of the Royal Society.

MATHEMATICAL WORK OF JOHN WALLIS, D.D., F.R.S.

By **J. F. SCOTT**, Ph.D., B.A.

12/6 net

"His work will be indispensable to those interested in the early history of The Royal Society. I commend to all Students of the Seventeenth Century, whether scientific or humane, this learned and lucid book."—Extract from foreword by Prof. E. N. da C. Andrade, D.Sc., Ph.D., F.R.S.
Recommended for publication by University of London

CORRESPONDENCE AND PAPERS OF EDMOND HALLEY

Arranged and Edited by **EUGENE FAIRFIELD MACPIKE**

21/- net

First published on behalf of The History of Science Society by Oxford University Press. Now reissued by Taylor & Francis, Ltd.

MEMOIRS OF SIR ISAAC NEWTON'S LIFE

By **WILLIAM STUKELEY**, M.D., F.R.S., 1752
From an Original Manuscript

5/- net

Now in the possession of the Royal Society, London

HEVELIUS, FLAMSTEED AND HALLEY

Three Contemporary Astronomers and their Mutual Relations
By **EUGENE FAIRFIELD MACPIKE**
Published by arrangement with The History of Science Society

12/6 net

Printed and Published by Taylor & Francis, Ltd. 7

ANNALS OF SCIENCE

A Quarterly Review of the History of Science

Founded in 1936, *Annals of Science* has come to occupy a secure place in the esteem of the historian of science as well as in the mind of everyone interested in the history of science in modern culture. It is recognized as an indispensable part of modern culture. Each volume consists of approximately 350 pp. in royal octavo, copiously illustrated with half-tone plates and text-figures.

Ann. Sub. £3 3 0 per vol., *post free* **17/6 per part,** *plus postage*

SEPTEMBER 1954

Jean-Jacques Rousseau : Botanist. By Sir GAVIN DE BEER, D.Sc., Hon. D.-ès-L., F.R.S. (Plates VIII and IX.)

The Early History of Laboratory Instruction in Chemistry at the Ecole Polytechnique, Paris, and elsewhere. By W. A. SMEATON, M.Sc., A.R.C.S.

Isaac Milner and the Jacksonian Chair of Natural Philosophy. By L. J. M. COLEBY, M.A., M.Sc., Ph.D.

Thomas Pennant and the Morris Brothers. By COLIN MATHESON, M.A., B.Sc., F.M.A. (Plate X.)

Biographical Note on John Symmons, F.R.S. By R. J. COLE, B.Sc., F.R.I.C., A.M.I.Chem.E.

Note. **Mechanical Aids to the Use of Literature.** By Professor J. R. PARTINGTON, M.B.E., D.Sc.

Review.

DECEMBER 1954

Chappe D'Auteroche : A Pathfinder for Astronomy. By ANGUS ARMITAGE, M.Sc., Ph.D.

James Watt's Letter to Joseph Priestley, 26 April 1783. By ROBERT E. SCHOFIELD, M.S.

Training Captains of Industry : The Education of Matthew Robinson Boulton [1770–1842] and the Younger James Watt [1769–1848]. By ERIC ROBINSON, M.A.

Erasmus Darwin's Botanic Garden and Contemporary Opinion. By ERIC ROBINSON, M.A.

A Bibliographical Study of the Introduction of Lavoisier's *Traité Élémentaire de Chimie* into Great Britain and America. By DENIS I. DUVEEN, F.R.I.C. and HERBERT S. KLICKSTEIN, M.D.

Augustin François Silvestre and the Société Philomathique. By DENIS I. DUVEEN, F.R.I.C.

Clerk Maxwell's Corrections to the Page Proofs of " A Dynamical Theory of the Electromagnetic Field ". By PAUL F. CRANEFIELD, Ph.D.

Fiscal Policy and the Development of Technology. By ARCHIBALD CLOW, M.A., D.Sc.

(*Subject to alteration up to the time of going to Press.*)

SCIENTIFIC PUBLICATIONS OF THE ROYAL SOCIETY

The scientific publications of the Royal Society are issued under two titles, *Philosophical Transactions of the Royal Society* and *Proceedings of the Royal Society*, each of which is divided into two series. Series A covers the mathematical and physical sciences while Series B covers the biological sciences.

Notice of change of publisher

The Council of the Royal Society wishes to bring to the attention of all subscribers to the *Proceedings* and *Philosophical Transactions* its decision to terminate as from 1 *October* 1954 its agreement with the Cambridge University Press (London Office) to act as the Society's publishers for these journals. The journals will still be printed by the Press at Cambridge, but the Society will publish them from its own offices at convenient dates after 1 October 1954.

After the operative dates all communications concerning the journals, i.e. subscriptions, orders, complaints, enquiries for back volumes, etc. should be addressed to

The Assistant Secretary,
The Royal Society,
Burlington House,
Piccadilly,
London, W.1.

PHILOSOPHICAL TRANSACTIONS

Issued in two series, A and B, at irregular intervals in paper covers at varying prices. Bound volumes are available.

SERIES A—VOL. 247 (*continued*)

A 925—4 NOVEMBER 1954

The lift and moment acting on a thick aerofoil in unsteady motion. By L. C. WOODS. Price **10/-.**

A 926—4 NOVEMBER 1954

On the decay of a normally distributed and homogeneous turbulent velocity field. By I. PROUDMAN and W. H. REID. Price **8/6.**

A 927—30 NOVEMBER 1954

The semi-diurnal tides along the equator in the Indian Ocean. By L. A FAIRBAIRN. Price **7/-.**

Scientific Publications of the Royal Society (*continued*)

A 928—30 NOVEMBER 1954

Homogeneous dynamos and terrestrial magnetism. By Sir EDWARD BULLARD, F.R.S. and H. GELLMAN. Price **21/-.**

A 929—28 DECEMBER 1954

Two-dimensional theory of elasticity for finite deformations. By J. E. ADKINS, A. E. GREEN and G. C. NICHOLAS. Price **8/6.**

A 930—28 DECEMBER 1954

The asymptotic solution of linear differential equations of the second order for large values of a parameter. By F. W. J. OLIVER. **The asymptotic expansion of Bessel functions of large order.** By F. W. J. OLIVER. Price **19/-.**

SERIES B—VOL. 238 (*continued*)

B 653—10 DECEMBER 1954

Elephantulus **going into anoestrus : menstruation and abortion.** By C. J. VAN DER HORST. **The lactation cycle of *Elephantulus myurus jamesoni* (Chubb).** By MURIEL J. MCKERROW. **The male genital system and reproductive cycle of *Elephantulus myurus jamesoni* (Chubb).** By ZELDA G. STOCH. Price **35/-.**

B 654—31 DECEMBER 1954

Observations on the cytology and taxonomy of the pteridophyte flora of Ceylon. By IRENE MANTON and W. A. SLEDGE. Price **£2 0 0.**

B 655—31 DECEMBER 1954

Sensitivity to light and the reactions to changes in light intensity of the echinoid *Diadema antillarum* Philippi. By N. MILLOT. Price **14/-.**

B 656—JANUARY 1955

The flight muscles of insects—their anatomy and histology : with some observations on the structure of striated muscle in general. By O. W. TIEGS, F.R.S. **The path of the slow contractile wave in arthropod muscle fibre.** By E. MATTHAEI and O. W. TIEGS, F.R.S. Price **£4 0 0.**

Scientific Publications of the Royal Society (*continued*)

PROCEEDINGS OF THE ROYAL SOCIETY

Issued in two series, A and B. Series A normally fortnightly, Series B irregularly. Subscriptions may be placed with the The Royal Society, payable *in advance of publication* of the four parts comprising the volume, at the following rates:

Volume in parts as issued: £3 5*s*. (*post free*); in the U.S.A. $11.00.
Cloth bound volume: £3 10*s*. (*post extra*).

Normal rates per part 18/– (*post extra*); cloth bound volume: £4 (*post extra*).

SERIES A

NO. 1164—21 OCTOBER 1954—VOL. 226 (Price 18/-)

A discussion on the first and second viscosities of fluids

Under the Leadership of L. ROSENHEAD, F.R.S.

Introduction. The second coefficient of viscosity: a brief review of fundamentals. By L. ROSENHEAD, F.R.S.

Vorticity generated by sound. By P. E. DOAK.

Acoustic experiments relating to the coefficients of viscosity of various liquids. By E. G. RICHARDSON.

Kinetic and thermodynamic aspects of the second coefficient of viscosity. By R. O. DAVIES.

The two coefficients of viscosity for an incompressible fluid containing air bubbles. By Sir GEOFFREY TAYLOR, F.R.S.

Note on the volume viscosity of water containing bubbles. By Sir GEOFFREY TAYLOR, F.R.S.

A note on Sir Geoffrey Taylor's paper. By R. O. DAVIES.

Transport and relaxation phenomena. By H. O. KNESER.

Acoustic streaming in liquids. By J. E. PIERCY and J. LAMB.

Ultrasonic measurements and the second viscosity of carbon disulphide. By J. H. ANDREAE and J. LAMB.

On the thermodynamic theory of the second viscosity. By J. MEIXNER.

Experimental determination of the second viscosity. By S. M. KARIM.

Note on the hydrodynamic and thermodynamic pressures. By J. G. OLDROYD.

The present status of the controversy regarding the bulk viscosity of fluids. By C. TRUESDELL.

Review of discussion. By E. N. DA C. ANDRADE, F.R.S.

Bakerian Lecture. The chemistry of the nucleotides. By A. R. TODD, F.R.S.

Studies in chain transfer. IV. Catalyzed polymerization of vinyl acetate. By SANTI R. PALIT and SURYYA KUMAR DAS.

Complex hyperfine structures in microwave spectra of covalent iridium compounds. By J. H. E. GRIFFITHS and J. OWEN.

The dynamic lateral instability of beams. By J. F. DAVIDSON.

The application of electronic digital computers to molecular orbital problems. I. The calculation of bond lengths in aromatic hydrocarbons. By H. O. PRITCHARD and F. H. SUMNER.

Competitive growth of lactose-positive and lactose-negative strains of *Bact. coli mutabile*. By A. C. R. DEAN and Sir CYRIL HINSHELWOOD, For.Sec.R.S. (Abstract.)

Scientific Publications of the Royal Society (*continued*)

NO. 1165—9 NOVEMBER 1954—VOL. 226 (Price 18/-.)

X-ray scattering from coals. By P. B. HIRSCH. (Plates 1 and 2.)

The electrostatic calculation of molecular energies. I. Methods of calculating molecular energies. By A. C. HURLEY.

The electrostatic calculation of molecular energies. II. Approximate wave functions and the electrostatic method. By A. C. HURLEY.

The electrostatic calculation of molecular energies. III. The binding energies of saturated molecules. By A. C. HURLEY.

The cross-sections and angular distributions of the D—D reactions between 150 and 450 keV. By G. PRESTON, P. F. D. SHAW and S. A. YOUNG.

The slip modes of titanium and the effect of purity on their occurrence during tensile deformation of single crystals. By A. T. CHURCHMAN.

An experimental investigation of the interaction between shock waves and boundary layers. By G. E. GADD, D. W. HOLDER and J. D. REGAN. (Plates 3 and 4.)

On the definition of finite operator quantities in quantum electrodynamics. By J. G. VALATIN.

Heats of mixing. By D. S. ADCOCK and M. L. MCGLASHAN.

NO. 1166—23 NOVEMBER 1954—VOL. 226 (Price 18/-.)

The Rutherford Memorial Lecture, 1954. Rutherford—his life and work, 1871–1937. By E. MARSDEN, F.R.S.

Internal rotation in dimethyl acetylene. By I. M. MILLS and H. W. THOMPSON, F.R.S.

The synthesis of block copolymers in a flow system. By J. A. HICKS and H. W. MELVILLE, F.R.S.

Note on the Whitehead-Rayner expanding universe. By J. L. SYNGE, F.R.S.

On the propagation of elastic waves in aeolotropic media. I. General principles. By M. J. P. MUSGRAVE.

On the propagation of elastic waves in aeolotropic media. II. Media of hexagonal symmetry. By M. J. P. MUSGRAVE.

The equations of motion in the non-symmetric unified field theory. By W. B. BONNOR.

The fine structure of the line 4686 Å of singly ionized helium. By G. W. SERIES.

The Stark effect in hydrogen-like spectra. By G. W. SERIES and K. W. H. STEVENS.

The second virial coefficients of mixtures and polar of non-polar vapours. By J. D. LAMBERT, S. J. MURPHY and A. P. SANDAY.

A study of the shape, surface structure and frictional wear of fibres by reflexion electron microscopy. By J. A. CHAPMAN and J. W. MENTER. (Plates 5 to 8.)

Infra-red spectra of polypeptides with small side chains. By A. ELLIOTT.

Scientific Publications of the Royal Society (*continued*)

NO. 1167—7 DECEMBER 1954—VOL. 226 (Price **18/-**)

Viscosity and the structure of molten silicates. By J. O'M. BOCKRIS and D. C. LOWE.

The electrical and thermal conductivities of monovalent metals. By J. M. ZIMAN.

The physics and chemistry of a self-sustained reaction between iron and potassium permanganate. By R. A. W. HILL.

Catalysis on evaporated metal films. V. Reactions between cyclic hydrocarbons and deuterium. By J. R. ANDERSON and C. KEMBALL.

Effect of chemical shift and J-coupling on nuclear resonance line-shape. By M. K. BANERJEE, T. P. DAS and A. K. SAHA.

Absorption cross-sections in the vacuum ultra-violet. II. The Schumann-Runge bands of oxygen (2000 to 1750 Å). By R. W. DITCHBURN and D. W. O. HEDDLE.

A new model for nuclear matter. By T. H. R. SKYRME.

The crystal structure of polyethylene terephthalate. By R. DE P. DAUBENY, C. W. BUNN and C. J. BROWN.

On expanding a hole from zero radius in a thin infinite plate. By J. M. ALEXANDER and H. FORD.

Index.

NO. 1168—21 DECEMBER 1954—VOL. 227 (Price **18/-.**)

The influence of molecular flexibility on the transfer of vibrational energy in hydrocarbons. By W. D. MCGRATH and A. R. UBBELOHDE, F.R.S.

Rates of polymerization in the system styrene, p-methoxystyrene and methyl methacrylate. By D. C. BLACKLEY, H. W. MELVILLE, F.R.S. and L. VALENTINE.

Irradiation of explosives with high-speed particles and the influence of crystal size on explosion. By F. P. BOWDEN, F.R.S. and K. SINGH. (Plates 1 and 2.)

The application of variational methods to atomic scattering problems. IV. The excitation of the 2^1S and 2^3S states of helium by electron impact. By H. S. W. MASSEY, F.R.S. and B. L. MOISEIWITSCH.

The coherent scattering of γ-rays by K electrons in heavy atoms. I. Method. By G. E. BROWN, R. E. PEIERLS, F.R.S. and J. B. WOODWARD.

The coherent scattering of γ-rays by K electrons in heavy atoms. II. The scattering of 0·32 mc^2 γ-rays in mercury. By SHEILA BRENNER, G. E. BROWN and J. B. WOODWARD.

The combustion of methane at high temperatures. By J. H. BURGOYNE and H. HIRSCH.

Renormalization of the transformation operators of quantum electrodynamics. By J. C. POLKINGHORNE.

Antiferromagnetism and ferromagnetism of non-stoichiometric compounds. By E. W. ELCOCK.

The thermal decomposition of ammonium perchlorate. I. Introduction, experimental, analysis of gaseous products, and thermal decomposition experiments. By L. L. BIRCUMSHAW and B. H. NEWMAN.

Secondary flow in a rotating straight pipe. By S. N. BARUA.

Scientific Publications of the Royal Society (*continued*)

SERIES B

NO. 910—15 DECEMBER 1954—VOL. 143 (Price 18/-)

A discussion on the physiology of man at high altitudes
Under the Leadership of Sir BRYAN MATTHEWS, F.R.S.

Limiting factors at high altitude. By Sir BRYAN MATTHEWS, F.R.S.

Acute anoxia. By W. K. STEWART.

Respiratory control in acute and prolonged hypoxia. By E. H. CHRISTENSEN.

The effect of altitude upon various nervous functions. By E. GRANDJEAN.

The effects of oxygen on acclimatized men at high altitude. By L. G. C. PUGH.

Some physiological requirements of oxygen systems. By H. L. ROXBURGH.

The use of oxygen apparatus by acclimatized men. By T. D. BOURDILLON.

Ventilatory capacity at altitude and its relation to mask design. By J. E. COTES.

High altitude deterioration. By M. WARD.

Quantitative studies on tissue transplantation immunity. I. The survival times of skin homografts exchanged between members of different inbred strains of mice. By R. E. BILLINGHAM, L. BRENT, P. B. MEDAWAR, F.R.S. and E. M. SPARROW.

Quantitative studies on tissue transplantation immunity. II. The origin, strength and duration of actively and adoptively acquired immunity. By R. E. BILLINGHAM, L. BRENT and P. B. MEDAWAR, F.R.S.

The effect of nitrate, iodide and bromide on the duration of the active state in skeletal muscle. By A. V. HILL, F.R.S. and L. MACPHERSON.

The correlation between relatives in a random mating population. By O. KEMPTHORNE.

An experimental study of the relation between the medial mamillary nucleus and the cingulate cortex. By W. M. COWAN and T. P. S. POWELL. (Plates 1 and 2.)

The cuticle of the cockroach *Periplaneta americana*. I. The appearance and histological structure of the cuticle of the dorsal surface of the abdomen. By R. DENNELL and S. R. A. MALEK.

Haemoglobin in *Artemia*. By BARBARA M. GILCHRIST.

THE JOURNAL OF THE QUEKETT MICROSCOPICAL CLUB

This Club was founded in 1865 for the purpose of affording to experienced microscopists, as well as to students, regular and frequent opportunities for an exchange of views on special subjects in which they are mutually interested, and also for promoting Field Excursions to the well-known collecting districts around the metropolis.
In 1951 the Photomicrographic Society, which was founded in 1911, was incorporated in the Club.

Published February and August **15/– per part,** ***plus postage***

AUGUST 1954

The Presidential Address. The Optimal Conditions for Visual Microscopy. By H. HARTRIDGE, M.A., M.D., Sc.D., M.R.C.P., F.R.S.

Reflecting Microscopes. By K. W. KEOHANE. (Plates 8 and 9)

Further Notes on 35 mm. Photomicrography. By H. A. DADE.

The Mirror-Cover: an Aid to Axial Illumination. By JOHN R. BAKER.

A New Rotifer, *Keratella canadensis*. By BRUNO BĒRZIŅŠ.

Proceedings and Reports.

Treasurer's Accounts for 1953.

Proceedings of the Quekett Microscopical Club, October 1953 to January 1954.

Committee's Report (Eighty-Eighth Annual Report) covering the year January to December 1953.

Obituary. CHARLES H. CAFFYN. (Plate 10)

Microscopists' Notebook.

Demonstrating the diffraction disc. By H. A. DADE.

An Accessory for Centring the Substage Condenser. By Dr. T. STEPHANIDES.

An Accessory to Diminish Glare in the Microscope Field. By Dr. T. STEPHANIDES.

First Published July, 1952

THE SCIENTIFIC WORK OF RENÉ DESCARTES 1596-1650

By

J. F. SCOTT, B.A., M.Sc., Ph.D.

With a Foreword by H. W. TURNBULL, M.A., F.R.S.

This book puts the chief mathematical and physical discoveries of Descartes in an accessible form and fills an outstanding gap upon the shelf devoted to the history of philosophy and science. There is to be found in this volume the considerable contribution that Descartes made to the physical sciences, which involved much accurate work in geometrical optics and its bearing upon the practical problem of fashioning lenses, as also the deeper problems of light and sight and colour. The careful treatment that Dr. Scott has accorded to the work of Descartes is very welcome. The book is well worth reading and will be an asset to all libraries. This publication is recommended and approved by the Publication Fund Committee of the University of London.

212 *pages*, 7″ × 10″, *amply illustrated.*

PRICE £1–0–0 NET

Printed & Published by

TAYLOR & FRANCIS LTD.

RED LION COURT, FLEET ST., LONDON, E.C.4

PROCEEDINGS OF THE PHYSICAL SOCIETY

1 Lowther Gardens, Prince Consort Road, London, S.W.7

Papers published in the *Proceedings of the Physical Society* are reports of original research in all of the many branches of physics. The publication is split into two sections, each published monthly. Section A is concerned mainly with microscopic physics and Section B with microphysics.

Ann. Sub. £5 5 0, *post free* **10/- per part,** *plus postage*

OCTOBER 1954—SECTION A

Les Méthodes Optiques d'Orientation Atomique et leurs Applications. By Prof. A. KASTLER.

Investigations of Atomic and Molecular Absorption Spectra : III—Ultra-Violet Absorption Spectra of Indium Vapour. By Mr. W. R. S. GARTON.

Galvomagnetic and Thermomagnetic Effects in a Plasma. Dr A. A. WARE.

The Beta Rays of Thallium 204. Dr. J. C. KNIGHT, Dr. T. H. BRAID and Dr. H. O. W. RICHARDSON.

The Deviations of Nuclear Magnetic Moments from the Schmidt Lines. By Dr. R. J. BLIN-STOYLE and Mr. M. A. PERKS.

X-Ray Measurements on Lithium at Low Temperatures. By Prof. E. A. OWEN and Dr. G. I. WILLIAMS.

On Feynman's Theory of Liquid Helium. By H. N. V. TEMPERLEY.

The Vibrational and Rotational Excitation of Molecular Hydrogen by Electron Impact. By Mr. T. R. CARSON.

The Photo-Ionization Cross Section of Lithium. Dr. A. L. STEWART.

Radiations from Water under Alpha-Particle Bombardment. By Dr. E. W. T. RICHARDS.

The Photo-Ionization of Neon. Dr. M. J. SMEATON.

Emission of Electron–Positron Pairs from Light Nuclei : III—γ-Transitions in the Reaction $^{15}N(p, \gamma)^{16}O$. By Dr. G. GOLDRING.

The Absorption Spectrum of Bismuth Selenide and Bismuth Telluride in the Region 2900–2200 Å. By Dr. C. B. SHARMA.

Research Notes :—

Vibrational Transition Probabilities of Diatomic Molecules : III. Dr. P. A. FRASER.

The Detection of Electron Pairs in a Cloud Chamber with Internal Counters. By Dr. P. J. CAMPION and Dr. W. T. DAVIES.

The Resolving Time of an Internal Counter Controlled Wilson Chamber. By Dr. P. J. CAMPION and Dr. W. T. DAVIES.

The Reaction $^{9}Be(d, ^{3}He)^{8}Li$. Mr. M. M. WINN.

Letters to the Editor.

Reviews of Books.

Proceedings of the Physical Society (*continued*)

OCTOBER 1954—SECTION B

The Lattice Spacings of Binary Tin-Rich Alloys. By Dr. L. A. JEE and Dr. G. V. RAYNOR.

Taylor Instability of the Interface between Superposed Fluids—Solution by Successive Approximations. By Dr. R. L. INGRAHAM.

The Approach to the Steady State in Gaseous Thermal Diffusion and its Application to Determining the Dependence of Gas Diffusivity on the Concentration Ratio. By Dr. P. T. NETTLEY.

Optical and Photo-Electrical Properties on Indium Antimonide. By Dr. D. G. AVERY, Dr. D. W. GOODWIN, Mr. W. D. LAWSON and Dr. T. S. MOSS.

Current Limitation in the Low-Pressure Mercury Arc. By Dr. J. E. ALLEN and Dr. P. C. THONEMANN.

The Interpretation of the Properties of Indium Antimonide. By Dr. T. S. MOSS.

The Vapour Pressure of Calcium : I. By Mr. P. E. DOUGLAS.

The Vapour Pressure of Calcium : II. By Dr. D. H. TOMLIN.

Corrigendum (TILLETT).

Reviews of Books.

NOVEMBER 1954—SECTION A

The Scattering of Nucleons by Alpha Particles—the s-Phases. Dr. S. HOCHBERG, Prof. H. S. W. MASSEY and Mr. L. H. UNDERHILL.

On the Neutron Spectrum for $v^{-\alpha}$ Absorption Cross Section. By Dr. B. DAVISON and Mrs. M. E. MANDL.

Radiations from the Proton Bombardment of ^{23}Na. By Dr. F. C. FLACK, Dr. J. G. RUTHERGLEN and Dr. P. J. GRANT.

Theory of (d, p) and (d, n) Reactions : I—General Theory Ignoring Coulomb Effects. By Mr. I. P. GRANT.

The D–D Reaction. By Dr. W. M. FAIRBAIRN.

The Sidereal Correlation of Extensive Air Showers. By Dr. F. J. M. FARLEY and Mr. J. R. STOREY.

Note on the Relation between certain Forbidden Beta Transitions and the Nuclear Spin Orbit Interaction. By Dr. G. N. FOWLER.

Inelastic Heavy-Particle Collisions Involving the Crossing of Potential Energy Curves : II—Charge Transfer from H-atoms to Al^{3+}, B^{2+}, Li^{2+} and Al^{2+}. By Dr. A. DALGARNO.

Research Notes :

On Antiferromagnetism in Metals. By Dr. R. H. TREDGOLD.

Riesz Potential and the Elimination of Divergences from Quantum Electrodynamics : III. Mr. L. S. KOTHARI.

Ferromagnetic Properties of Oxidized Mn_2Sb. By Dr. G. D. ADAM and Dr. K. J. STANDLEY.

Letters to the Editor.

Reviews of Books.

Proceedings of the Physical Society (*continued*)

NOVEMBER 1954—SECTION B

Field Aberrations in Wide Aperture Optical Systems. By Mr. W. S. S. BLASCHKE.

Cathodo-Luminescence of MgO. By Dr. B. D. SAKSENA and Mr. L. M. PANT.

Luminescence Characteristics of Some Scintillating Crystals. By Mr. J. R. COOK and Mr. K. A. MAHMOUD.

Out-of-Focus Diffraction Patterns for Microscope Objectives. By Dr. R. O. GANDY.

Mechanisms of Creep in a Precipitation Hardened Alloy. By Dr. G. C. E. OLDS.

Research Notes :

The Secondary Electron Emission of Sodium and Zinc. By Dr. J. WOODS.

An Apparatus for Heat-Treatment and Quenching Small Specimens in a Vacuum from High Temperatures. By Mr. T. H. SCHOFIELD.

Letters to the Editor.

Reviews of Books.

DECEMBER 1954—SECTION A

The Time Coherence of Associated Cosmic Ray Particles. By Mr. V. C. OFFICER and Mr. P. J. ECCLES.

The Angular Correlation of Successive γ-rays in ^{60}Ni at Low Temperatures. By Mr. H. R. LEMMER and Dr. M. A. GRACE.

Plasma Oscillations in a Periodic Potential : The One-Zone Theory. By Mr. J. HUBBARD.

Inelastic Collisions between Heavy Particles : III—Excitation of Helium Atoms in Fast Encounters with Hydrogen Atoms, Protons and Positive Helium Ions. By Dr. B. L. MOISEIWITSCH and Dr. A. L. STEWART.

Electron Capture : IV—Capture from Helium Atoms by Fast Protons. By Dr. B. H. BRANSDEN, Dr. A. DALGARNO and Mr. N. M. KING.

The Elastic Scattering of Electrons by the Excited 2s and 2p States of Atomic Hydrogen. By Dr. P. SWAN.

A Cloud Chamber Study of some Aspects of the Geiger Discharge. By Dr. P. J. CAMPION.

Research Notes :

Phase of Matrix Elements in Nuclear Reactions and Radioactive Decay. By Dr. R. HUBY.

An Investigation of the (γ, n) Reaction in Cu, Zn and Ag. By Mr. D. ST. P. BUNBURY.

Levels of ^{24}Mg from the ^{27}Al(p, α)^{24}Mg Reaction. By Dr. G. W. GREENLEES.

On Source Scattering in Angular Correlation Experiments with Soft Electrons. By Dr. E. BREITENBERGER.

Letters to the Editor.

Reviews of Books.

Obituary Notices.

Subject Index, Section A, Vol. 67.

Index of Authors (with Titles), Section A, Vol. 67.

Index to Reviews of Books, Section A, Vol. 67.

Proceedings of the Physical Society (*continued*)

DECEMBER 1954—SECTION B

Diffusion and Mass Transport in Tubes (Guthrie Lecture). By Sir GEOFFREY TAYLOR.

The **Effect of Intense Magnetic Fields on Electroluminescent Powder Phosphors.** By Mr. A. N. INCE.

The **Effect of Particle Shape Variations on the Coercivity of Iron Oxide Powders.** By Mr. W. P. OSMOND.

On the Abrasion of Rubber. By Dr. A. SCHALLAMACH.

Research Notes :

Electrical Conductivity of Some Condensed Aromatic Hydrocarbons. By Mr. D. C. NORTHROP and Dr. O. SIMPSON.

Symmetry of Vibrating Square Membrane. By Dr. MARY D. WALLER.

Note on Surface Vibrations of a Circumscribed Liquid. By Dr. MARY D. WALLER.

Reviews of Books.

Obituary Notices.

Subject Index, Section B, Vol. 67.

Index of Authors (with Titles), Section B, Vol. 67.

Index of Reviews of Books, Section B, Vol. 67.

REPORTS ON PROGRESS IN PHYSICS

VOLUME XVII (1954)

Nuclear Shell Structure. By M. H. L. PRYCE.

Diffraction Theory. By C. J. BOUWKAMP.

Atmospheric Electricity. By J. ALAN CHALMERS.

The Physical Condition of the Solar Corona. By C. W. ALLEN.

Theory of Origin of Cosmic Rays. By EDWARD TELLER.

Atomic Valence States and Chemical Binding. By W. MOFFITT.

Antiferromagnetism. By A. B. LIDIARD.

Horizontal Movements in the Ionosphere. By B. H. BRIGGS and M. SPENCER.

Price to Non-Fellows £2 10*s. net* (*Postage* 1*s.* 6*d.*)

Price to Fellows (*one copy*) £1 17*s.* 6*d. net* (*Postage* 1*s.* 6*d.*)

ROYAL ASTRONOMICAL SOCIETY : MONTHLY NOTICES

Burlington House, Piccadilly, London, W.1

First published in 1827, the *Monthly Notices* of the Royal Astronomical Society soon became the recognized British medium for reporting original research in theoretical and observational astronomy. Six issues now appear each year. Since 1922 the *Geophysical Supplement*, published twice a year, has performed a like function for research in all branches of geophysics except meteorology.

Ann. Sub. £4 4 0, *post free* **13/6 per part,** *plus postage*

VOL. 114, NUMBER 1—1954

Meeting of 1954 January 8 :

Fellows elected.

Junior Member elected.

Presents announced.

Award of the Gold Medal to Dr. W. Baade.

On the intensities of interlocked multiplet lines in the Milne-Eddington Model. By I. W. BUSBRIDGE and D. W. N. STIBBS.

Motions in the Sun at the photospheric level. IV. The equatorial rotation and possible velocity fields in the photosphere. By A. B. HART.

Theory of the meteor height distribution obtained from radio-echo observations. I. Shower meteors. By T. R. KAISER.

Theory of the meteor height distribution obtained from radio-echo observations. II. Sporadic meteors. By T. R. KASIER.

Scale heights and pressures in the upper atmosphere from radio-echo observations of meteors. By S. EVANS.

An analysis of bursts of solar radio emission and their association with solar and terrestrial phenomena. By R. D. DAVIES.

The helium star HD 168476. By A. D. THACKERAY.

Photometric effects of reflection in close binary systems. By ZDENĚK KOPAL.

Intermediate coupling line strengths. By R. H. GARSTANG.

Mean areas and heliographic latitudes of sunspots in the year 1950. ROYAL GREENWICH OBSERVATORY.

VOL. 114, NUMBER 2—1954

Photoelectric investigations of solar corpuscular radiation, I. By M. J. SMYTH.

Electron temperatures and electron densities in planetary nebulae. By M. J. SEATON.

Metallic ammonium. By M. J. M. BERNAL and H. S. W. MASSEY.

On the interpretation of the extragalactic red-shifts. By G. J. WHITROW.

A study of the equilibrium of globular clusters. By R. v. D. R. WOOLLEY.

The bending of a square plate on a spherical former with applications to the photographic plate of a Schmidt camera. By W. M. SHEPHERD and D. RADENKOVIĆ.

Magnitudes and colours of 123 stars in the neighbourhood of the Sun. By G. G. YATES.

Royal Astronomical Society: Monthly Notices (*cont.*)

Meteor stream-widths and radiant deviations. By FRED L. WHIPPLE and FRANCES W. WRIGHT.

On the occurrence of commensurable mean motions in the solar system. By A. E. ROY and M. W. OVENDEN.

Further measurements to detect a general magnetic field of the Sun. By H. VON KLÜBER.

The spectroscopic double-lined binary HD 77464. By M. W. FEAST.

Motions in the Sun at the photospheric level. V. Velocities of granules and of other localized regions. By H. H. PLASKETT.

Summary of paper published in the *Memoirs of the R.A.S.*:
Photographic and photovisual magnitudes of 7^m–10^m stars in the +15° Selected Areas. By A. BEER, R. O. REDMAN and G. G. YATES.

GEOPHYSICAL SUPPLEMENT

Price 10/6 *post free*

VOL. 7, NUMBER 1—OCTOBER 1954

Magnetic perturbations of invar pendulums used for relative gravity measurements. By A. H. COOK.

A laboratory investigation of the second order corrections to gravity measured at sea. By J. C. HARRISON.

The natural permanent magnetization of the Lower Basalts of Northern Ireland. By J. HOSPERS and H. A. K. CHARLESWORTH.

Note on the dynamics of storm-surges. By J. PROUDMAN.

OCCASIONAL NOTES

VOL. 3, NUMBER 17—OCTOBER 1954

Price 3/6 *post free*

Editorial Note.

The orthodox theory of the expanding universe. By G. J. WHITROW.

Transitions to metallic phases. By W. H. RAMSEY.

Some design considerations for large reflectors. By G. M. SISSON.

Ephemeris time. By D. H. SADLER.

ROYAL ASTRONOMICAL SOCIETY: MEMOIRS

VOL. LXVII—PART I—1954

Price £1.

Photographic and Photovisual Magnitudes of 7^m–10^m stars in the +15° Selected Areas. By A. BEER, R. O. REDMAN and G. G. YATES.

ANNALS & MAGAZINE OF NATURAL HISTORY

Incorporating 'The Journal of Botany'

Probably few independent scientific journals have such a long history as the 'Annals'. Formed by the merging of two periodicals, one dating from 1828 (*The Magazine of Natural History and Journal of Zoology, Botany, Mineralogy, Geology and Meteorology*) and one from 1838 (*The Annals of Natural History, or Magazine of Zoology, Botany and Geology*), it has apppeared continuously since 1840 under its present title: *The Annals & Magazine of Natural History, including Zoology, Botany and Geology.*

Ann. Sub. £6 0 0, *post free* **10/– per part,** *plus postage*

OCTOBER 1954

New Brachiopoda from the Eocene of England, France and Africa. By GRAHAM F. ELLIOTT. (Plate XV.)

The Early Lophophore and Subsequent loop (*Brachiopoda*). By GRAHAM F. ELLIOTT. (Plate XVI.)

Description d'une nouvelle espèce de genre *Oxymegaspis* **des Philippines (Homoptera, Cercopidae).** By V. LALLEMAND.

Quaternary Foraminifera from St. John's Fjord, West Spitsbergen. By R. N. C. BOWEN, Ph.D., B.Sc., F.G.S., Department of Geology, University College, Exeter.

Descriptions of Nine Species of Small Spores from the British Coal Measures. By M. A. BUTTERWORTH and R. W. WILLIAMS (Scientific Dept., National Coal Board). (Plates XVII–XIX.)

The Coral Genus *Halysites* **Fischer Von Waldheim.** By H. DIGHTON THOMAS, M.A., Ph.D., F.G.S., and STANLEY SMITH, M.A., D.Sc., F.G.S., Department of Geology, British Museum (Natural History). (Plates XX–XXII.)

Apogonid Fishes of the Subfamily Pesudamiinae from South-east Africa. By Professor J. L. B. SMITH, S.A. Council for Scientific and Industrial Research Fellow in Ichthyology, Rhodes University, Grahamstown, South Africa. (Plate XXIII.)

Bibliographical Notices:

Parrots and Parrot-like Birds. By THE DUKE OF BEDFORD.

The Observer's Book of Common Fungi. By E. M. WAKEFIELD, O.B.E.

NOVEMBER 1954

Fishes of East Africa, with New Records and Descriptions of Two New Species. By JAMES E. MORROW, Bingham Oceanographic Laboratory, Yale University. (Plates XXIV–XXV.)

On some Nematodes from Indian Vertebrates. I. Birds. By WILLIAM G. INGLIS, B.Sc., Department of Zoology, British Museum (Natural History).

A New Species of *Trombicula* **(Acarina: Trombiculidae) from Bats from Northern Australia.** By H. WOMERSLEY, South Australian Museum.

Annals & Magazine of Natural History (*continued*)

Studien **über Mallophagen aus den Sammlungen des Britischen Museums (Nat. Hist.) London. II. Das Amblycerengenus** *Actornithophilus* **Ferris, 1916.** Von G. TIMMERMANN, Hamburg. (Plate XXVI.)

A Note **on the Food of** *Chaetogaster diaphanus*. By J. GREEN, Bedford College, University of London.

New **Species of South American** *Cryptophalus* **(Col., Chrysomelidae).** By G. E. BRYANT, Commonwealth Institute of Entomology.

A New Genus and Species of Saldidae (Hemiptera-Heteroptera) from the Seychelles. By E. S. BROWN (Commonwealth Institute of Entomology).

A Note **on the Colobus Monkeys of the Gold and Ivory Coasts.** By A. H. BOOTH, Department of Zoology, University College of the Gold Coast.

Aberrant Serraniform Fishes from East Africa. By Professor J. L. B. SMITH, S.A. Council for Scientific and Industrial Research Fellow in Ichthyology, Rhodes University, Grahamstown, South Africa. (Plate XXVII.)

New **Species of Ferns from the Gold Coast.** By C. D. ADAMS, Botany Department, University College of the Gold Coast. (Plates XXVIII–XXIX.)

Bibliographical Notices :

The World in Pictures : No. 1, Icebergs and Jungles : No. 2, Mountains and Valleys. By SHIRLEY CARPENTER, MARIE NEURATH and STEWART IRWIN.

Irish Landscape, as seen by a Naturalist. By R. LLOYD PRAEGER.

Natural History Study. University of London Award.

Badgers' Year. By F. HOWARD LANCUM, M.B.E., F.L.S.

December number in course of preparation

THE FAUNA OF BRITISH INDIA

including Ceylon and Burma

The following volumes are still available :

BIRDS. (*Second Edition*). By E. C. STUART BAKER.
Vol. I. Vol. II. Vol. III. **30/-** each volume.

REPTILIA and BATRACHIA. (*Second Edition*).
By MALCOLM A. SMITH.
Vol. I.—**15/-** Vol. II.—**30/-**

BUTTERFLIES. (*Second Edition*). By G. TALBOT.
Vol. I.—**35/-** Vol. II.—**55/-**

Also, volumes on

LEPIDOPTERA	ODONATA
COLEOPTERA	MOLLUSCA
HYMENOPTERA	OLIGOCHÆTA
DIPTERA	HIRUDINEA
ARACHNIDA	CESTODA
RHYNCHOTA	NEMATODA
ORTHOPTERA	CŒLENTERATA
DERMAPTERA	PROTOZOA

A fully detailed list of these volumes will be supplied, free of charge, on application to :

TAYLOR & FRANCIS, LTD.
RED LION COURT, FLEET ST., E.C.4
SCIENTIFIC PRINTERS AND PUBLISHERS

Established over 150 years.

LONGMANS
Important Chemical Reference Books

CHEMICAL THERMODYNAMICS

I. PRIGOGINE and R. DEFAY

Translated by

D. H. EVERETT, B.Sc., D.Sc., D.Phil., M.A.

This is the first volume of a Treatise on Thermodynamics which will be completed in three volumes. The work is intended as an advanced textbook for honours students, and research workers. Volume I 63*s. net*

Completion of

AN ADVANCED TREATISE ON PHYSICAL CHEMISTRY

J. R. PARTINGTON, M.B.E., D.Sc.

This volume which completes this comprehensive treatise on advanced chemistry deals with molecular spectra and molecular structure, and with dielectrics and dipole moments. The first part assumes no previous knowledge and the necessary mathematics is given in the text. Special attention is given to valency and modern views on structure. The section on dielectrics includes alternating current theory and modern shortwave methods. Dipole moments are treated very completely, both from the experimental and theoretical sides, and examples of their use are given. There is a short treatment of ferroelectrics. 80*s. net*

Supplement to

MELLOR'S TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY

The supplement to Mellor's Treatise on Inorganic and Theoretical Chemistry will be comprised of a series of volumes, keyed closely to the original, presenting all the new matter published since the original date of compilation.

Supplementary Volume 1, *The Halogens.*
Publication 1955

6–7 Clifford Street, London, W.1

NEW BOOKS

Mathematics for the Chemist

By Professor G. J. Kynch, University College of Wales, Aberystwyth. Price **30s.**

This book will resolve a difficulty long familiar to chemists: that of deciding when a particular mathematical method can be applied to a problem, and when it cannot. Its purpose is to provide a text on the application of mathematics to the physical sciences, using the language of the chemist wherever possible.

Progress in Stereochemistry

Edited by W. Klyne, M.A., Ph.D., University of London Postgraduate Medical School. Price **50s.**

This book discusses some of the major advances of stereochemistry which have occurred over the last twenty years.

Contents: Shape of Simple Molecules. Conformation of Six-membered Ring Systems. Stereochemical Factors in Reaction Mechanisms and Kinetics. Stereochemistry and Spectroscopic Properties of Organic Compounds. Correlation of Configurations. The Hydrogen Bond. Compounds of High Molecular Weight. Stereospecificity of Enzyme Reactions. Complex Compounds. Bond Lengths and Valency Angles.

Solvent Properties of Amphiphilic Compounds

By P. A. Winsor, D.Sc., Shell Petroleum Co., Ltd. Price **40s.**

Gives a unified account of the phase behaviour, physical properties and solubilising action not only of the more typical soaps and detergent solutions, but also of hydrotropic salts and of the so-called "non-ionic emulsifiers."

Electrolyte Solutions

By R. A. Robinson, D.Sc., Ph.D., F.R.I.C., Professor of Chemistry, University of Malaya, and R. H. Stokes, Ph.D., D.Sc., F.R.A.C.I., A.R.I.C., Reader in Physical Chemistry, University of Western Australia. Price **56s.**

A detailed account of the present state of knowledge of some of the most fundamental properties of electrolytes, conductance, chemical potential and diffusion, from the standpoint of the practical electrochemist.

Modern experimental methods are discussed at some length, and extensive results are given, together with numerous tables useful in computations on electrolyte solutions.

Chemisorption

By B. M. W. Trapnell, M.A., Ph.D., Lecturer in Chemistry, Liverpool University. Price **35s.**

This work is designed to give a balanced presentation of the subject of chemisorption, in particular of discoveries made over the last fifteen years. The main part of the book, concerned with chemisorption itself, treats velocities of adsorption and desorption, equilibrium at surfaces, heats and mechanisms of adsorption, and the mobility of adsorbed layers. The two final chapters illustrate the relationship of chemisorption to heterogeneous catalysis and discuss the causes of catalytic specificity together with the mechanisms of some simple catalytic reactions. These include olefine hydrogenation and the cracking of hydrocarbons.

Numerical Methods

By A. D. Booth, D.Sc., Director of Electronic Computer Project, Birkbeck College, London University. Price **35s.**

This book has been planned to give an understanding of the basic principles on which numerical analysis rests, and therefore approaches the subject from this aspect rather than giving instruction in the details of actual calculation.

It is particularly directed to those wishing to acquire the art of programming for automatic calculators, for which a thorough knowledge of the underlying mathematical principles is essential, but where the actual details of calculation are carried out automatically.

BUTTERWORTHS

The pages of "Engineering" contain the most authoritative reports covering every field of engineering on land, sea or in the air, and are a constant source of information and ideas. The advertising columns regularly carry the announcements of the major engineering industrialists of Great Britain.

The Journal of Ideas

ENGINEERING

Offices 35 & 36, Bedford St. Strand, London W.C.2.

In the interest of *accuracy*

In the field of scientific photography, where performance must be capable of prediction and control within close limits, the consistently high quality of Ilford products has more than usual significance. This accounts for the regular use of Ilford sensitised materials by scientific and industrial research organizations both great and small, in every part of the world.

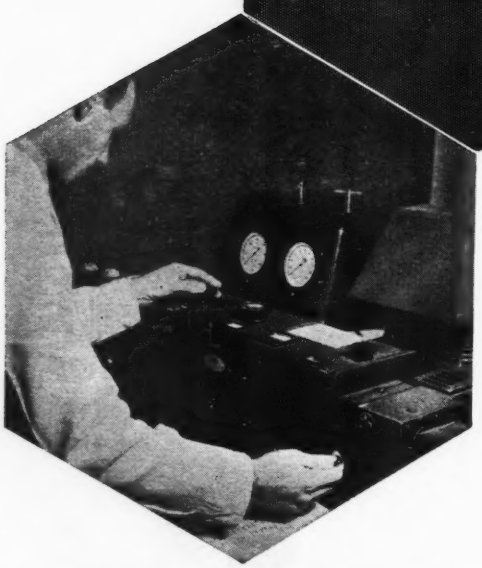
ILFORD

PHOTOGRAPHIC MATERIALS
in the Service of Science

ILFORD LIMITED · ILFORD · LONDON

H&W

Chemicals for Science



Hopkin & Williams Ltd. have been famous over 100 years for the manufacture of pure chemicals for research and analysis. From the early days of the company until the present day, with over 5,000 items listed in the H & W Chemical Catalogue, we have continuously maintained a high standard for all the listed ranges of chemicals, ' AnalaR ' Reagents being a particular example. Modern Research, Development and Analytical Laboratories, plus an efficient warehousing organisation enable us to meet the growing and often urgent needs of every branch of science.

Hopkin & Williams Ltd. are associated with Baird & Tatlock (London) Ltd., Howards of Ilford Ltd., and W. B. Nicolson (Scientific Instruments) Ltd. As a member company of Scientific Exports (Great Britain) Ltd., we are able to supply laboratories all over the world with a complete and comprehensive service.

HOPKIN & WILLIAMS Limited

Manufacturers of pure chemicals for Research and Analysis

FRESHWATER ROAD, CHADWELL HEATH, ESSEX

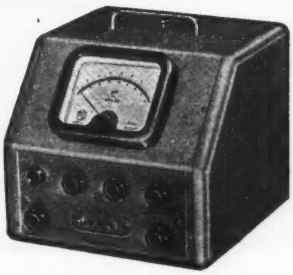
Member of SCIEX

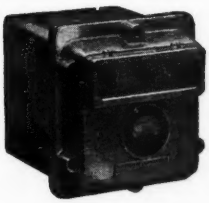
SCIENTIFIC PYE INSTRUMENTS

Pye pH measuring equipment is now being used in many fields where accuracy, stability and ease of operation are the overriding criteria. The electronic unit, which forms the basis of the Pye pH metering range, has been thoroughly proved by continuous use in many leading research laboratories.

PYE UNIVERSAL pH METER
(Cat. No. A.S. 11066)

Portable — Direct reading 0-14 pH — Mains operated—Full mains stabilization —Manual or automatic temperature compensation—Open or enclosed electrode assemblies included—adaptable to virtually all applications.



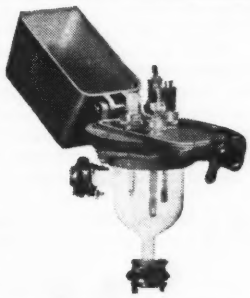


PYE INDUSTRIAL pH AMPLIFIER
(Cat. No. A.S. 11400)

Links with standard controllers and recorders — Flame-proof case to B.S.S. 229/1946 — Full automatic temperature compensation—three ranges, 0-8, 3-11, 6-14.

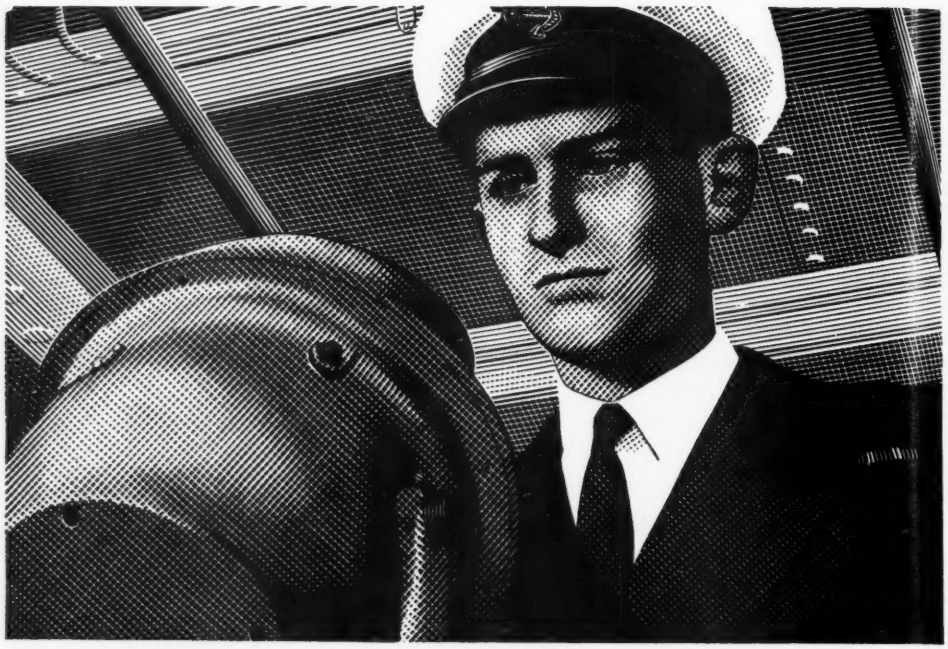
INDUSTRIAL CONTINUOUS-FLOW pH ELECTRODE ASSEMBLY (Cat. No A.S.11420)

Glass Flow Chamber—Splash-proof Housing — Components easily accessible and replaceable—Full range 0-14 pH.
(Immersion Assembly also available.)



Our pH Department is available to advise on research or industrial measurement problems.

W. G. PYE & CO. LTD., GRANTA WORKS, CAMBRIDGE, ENGLAND
Telephone: Cambridge 4032 Telegrams: Pye—Cambridge



PROGRESS IN ELECTRONICS

Despite its innumerable applications, the magnet is still popularly associated with its use as a navigational aid. This is perhaps not surprising when one considers that the earliest experiments in magnetism were connected with the compass and its use in navigation.

It is said that the Chinese were using a form of lodestone compass in B.C. 2637, but the experimental study of magnetic direction finding devices really began in A.D. 1000 and reached something of a milestone in the 16th century with the work of Dr. Gilbert, who was physician to Queen Elizabeth.

It is only within the last twenty years, however, that revolutionary advances have been made in navigational aids. Radar was, of course, the most important of these advances and it owed its successful development to the invention of an electronic tube known as a magnetron, and this device, in turn, depended for its efficiency upon the "Ticonal" permanent magnet—an alloy having great field strength, stability and uniformity.

Mullard's work in the field of magnetic materials has been particularly outstanding. In addition to "Ticonal" permanent magnets, two other materials now in quantity production are Magnadur, a non-metallic permanent magnet, and Ferroxcube, a non-metallic H.F. core material. These materials are contributing to important developments in other electronic applications such as television receivers and line communications equipment.

Progress in magnetic materials continues, and through this the future may well see developments of equal significance to those which have gone before.

Mullard

MULLARD LIMITED, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

Factories at:

Blackburn Fleetwood Gillingham Hove Lytham-St. Anne's Mitcham Padiham Rawtenstall Waddon Wandsworth Whyteleafe

MP5141K

BRITISH ASSOCIATION PUBLICATIONS

BIOLOGICAL SCIENCES IN BRITISH SCHOOLS

A Committee of the British Association has completed a survey of the position of the Biological Sciences in British Schools. Their report deals with primary, secondary and secondary modern Schools and contains information not elsewhere available about methods of teaching biology, the status of biology in the school curriculum, the importance of field work in biological education, factors that affect the demand and supply of teaching staff and many other subjects of interest to teachers and administrators of education.

Copies of the report, price 1/–, can be obtained from the office of the British Association, Burlington House, Piccadilly, London, W.1 (by post 1s. 2d.).

List of the Principal Publications

On sale at the Office of the British Association, Burlington House, Piccadilly, London, W.1

THE ADVANCEMENT OF SCIENCE, quarterly 7*s.* 6*d.* plus postage 3*d.*; annual subscription £1 5*s.*, *post free.*

SCIENTIFIC SURVEYS of various districts in which the Association has met since 1932 :—

York, Aberdeen, Blackpool, Nottingham, 2*s.* each, plus postage 2*d.*; Newcastle-upon-Tyne (1949), 10*s.*, plus postage 6*d.*; S.E. Scotland (1951), 15*s.*, plus postage 6*d.*; Belfast in its Regional Setting (1952), 21*s.* plus postage 8*d.*

RECENT REPRINTS, *post free :*

Modern Theories of the Origin of the Universe, *by Prof. H. Dingle*, 1949, 1*s.* 2*d.*

Non-Linear Vibrations, *by Dr. Mary L. Cartwright*, 1949, 1*s.* 2*d.*

Operational Research in War and Peace, discussion, 1947, 1*s.* 2*d.*

Science and the Adventure of Living, *by Sir Lawrence Bragg*, 1950, 1*s.* 2*d.*

CORPORATE MEMBERSHIP

Firms, research associations, local and other authorities can maintain profitable contacts with the whole field of science by becoming Corporate Members of the British Association. The present list of Corporate Members includes:

W. H. Allen, Sons & Co., Ltd.
Associated Electrical Industries, Ltd.
Associated Ethyl Co., Ltd.
Association of Assistant Mistresses in Secondary Schools.
Babcock & Wilcox, Ltd.
Blackpool Education Committee.
Booth Museum, Brighton.
British Electricity Authority.
British Thomson-Houston Co., Ltd.
Cheshire County Education Committee.
City and Guilds of London Institute.
Wm. Denny & Bros., Ltd.
Derbyshire County Council.
Distillers Co. (Biochemicals) Ltd.
Drysdale & Co., Ltd.
Educational Institute of Scotland.
"Engineering," Ltd.
Ferranti, Ltd.
Heriot-Watt College.
Incorporated Association of Asst. Masters in Secondary Schools.
Institution of Professional Civil Servants.
Joseph Lucas, Ltd.
Macmillan & Co., Ltd.
Metropolitan Vickers Electrical Co., Ltd.
Murphy Radio, Ltd.
C. A. Parsons & Co., Ltd.
Parsons Marine Steam Turbine Co., Ltd.
Peter Brotherhood, Ltd.
Production Engineering Ltd.
Society for the Promotion of Nature Reserves.
South-West Scotland Electricity Board.
Vickers Armstrong, Ltd.
Wallsend Slipway & Engineering Co., Ltd.
Whiteley Mills Ltd.
Yarrow & Co., Ltd.

Corporate Members are entitled to send as many as five representatives to the Annual Meeting of the Association and to receive publications.

New Corporate Members will be welcomed by the Council and particulars of Membership will be sent on application to the Secretary, British Association, Burlington House, London, W.1.

SCIENTIFIC BOOKS

Messrs. H. K. LEWIS can supply from stock or to order any book on the Pure and Applied Sciences. Catalogues on request.

CONTINENTAL AND AMERICAN works unobtainable in this country can be secured under Board of Trade licence.

SECOND-HAND SCIENTIFIC BOOKS

An extensive stock of books in all branches of Pure and Applied Science may be seen in this department. Large and small collections bought. Back volumes of Scientific Journals.

SCIENTIFIC LENDING LIBRARY

Annual Subscription from Twenty-five shillings. *Prospectus post free on request.*

THE LIBRARY CATALOGUE, revised to December, 1949. Pp. xii + 1152. To subscribers 17s. 6d. net., to non-subscribers 35s. net.; postage 1s. 6d. Supplement 1950 to 1952. To subscribers 3s. net; to non-subscribers 6s. net; postage 6d. Bi-monthly List of New Books, and new editions added to the Library sent post free to subscribers regularly.

Telephone: EUSton 4282
Telegrams: "Publicavit, Westcent, London"

H. K. LEWIS & Co. Ltd.

136 GOWER STREET, LONDON, W.C.1

Established 1844

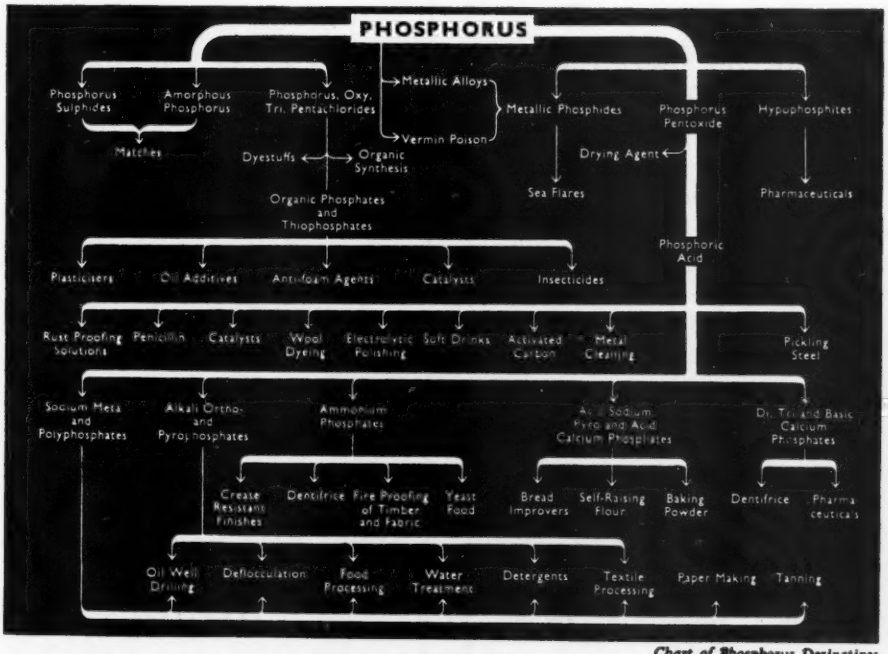


Chart of Phosphorus Derivatives

Manufactured by

ALBRIGHT & WILSON LTD

49 PARK LANE · LONDON · W.1 · WORKS: OLDBURY & WIDNES

A20

Technical Books

The Microtomist's Formulary and Guide
By PETER GRAY, Ph.D., F.R.M.S.
Med. 8vo. 794 pages. Illustrated. **65s.**

Irrigated Soils Their Fertility and Management
By D. W. THORNE and H. B. PETERSON
The Second Edition of one of the first books to present irrigation in relation to other soil management practices.
Demy 8vo. 392 pages. Illustrated. **45s.**

Elements of Statistical Mechanics
By D. ter HAAR
Demy 8vo. 468 pages. **45s.**

Introduction to Modern Algebra and Matrix Theory
R. A. BEAUMONT and R. W. BALL
Demy 8vo. 331 pages. **30s.** *net*

Freshwater Microscopy
By W. J. GARNETT, M.Sc., F.R.M.S.
Demy 8vo. 300 pages. Illustrated **30s.** *net*

Bread
The Chemistry and Nutrition of Flour and Bread with an Introduction to their History and Technology.
By LORD HORDER, G.C.V.O., M.D., F.R.C.P.; SIR CHARLES DODDS, M.V.O., M.D., D.Sc., F.R.C.P., F.R.S.; and T. MORAN, C.B.E., D.Sc., Ph.D.
Demy 8vo. Illustrated. **18s.** *net*

Active Networks
By C. V. RIDEOUT
This book is intended primarily for those who have studied the physics of vacuum tubes and related devices as well as the fundamentals of the theory of passive linear networks.
Demy 8vo. 485 pages. **42s.** *net*

●

Constable & Co. Limited
10-12 Orange Street · London, W.C.2

SOME NEW OXFORD BOOKS

Two new volumes in
The International Series of Monographs on Physics

Dynamical Theory of Crystal Lattices
BY MAX BORN AND KUN HUANG 50*s. net*

Meteor Astronomy
BY A. C. B. LOVELL 60*s. net*

Elementary Qualitative Analysis on the Small Scale
BY PETER WOODWARD
12*s.* 6*d. net*

An Introduction to The Theory of Numbers
BY THE LATE G. H. HARDY AND E. M. WRIGHT
Third Edition 42*s. net*

An Introduction to Plant Physiology
BY W. O. JAMES
Fifth Edition 17*s.* 6*d. net*

OXFORD UNIVERSITY PRESS
Amen House, Warwick Square, London, E.C.4.

Three "Electronic Engineering" Monographs

RESISTANCE STRAIN GAUGES

Price 12/6d.

By J. YARNELL, B.Sc., A.Inst.P. *(Postage 6d.)*

This book deals in a practical manner with the construction and application of resistance strain gauges and with the most commonly used circuits and apparatus. The strain-gauge rosette, which is finding ever wider application, is treated comprehensively, and is introduced by a short exposition of the theory of stress and strain in a surface.

ELECTROPHYSIOLOGICAL TECHNIQUE

Price 12/6d.

By C. J. DICKINSON, B.A., B.Sc. (*Magdalen College, Oxford*) *(Postage 6d.)*

The author describes the use of electronic methods as applied to research in Neurophysiology. Chapters are devoted to amplifying, recording and stimulating techniques used in physiology and medicine (e.g. electrocardiography, electroencephalography, etc.).

VOLTAGE STABILIZERS

Price 12/6d.

By F. A. BENSON, M.Eng., A.M.I.E.E., M.I.R.E. *(Postage 6d.)*

The subject of voltage stabilization is now very extensive and the newcomer will experience considerable difficulty in extracting the information required from the mass of published literature in a wide range of scientific periodicals. This monograph aims at removing such difficulties by reviewing the various methods of stabilization in use.

ELECTRONIC ENGINEERING

28 ESSEX STREET, STRAND, LONDON, W.C.2

To calculate the shape of cotton thread spinning at high speed . . .

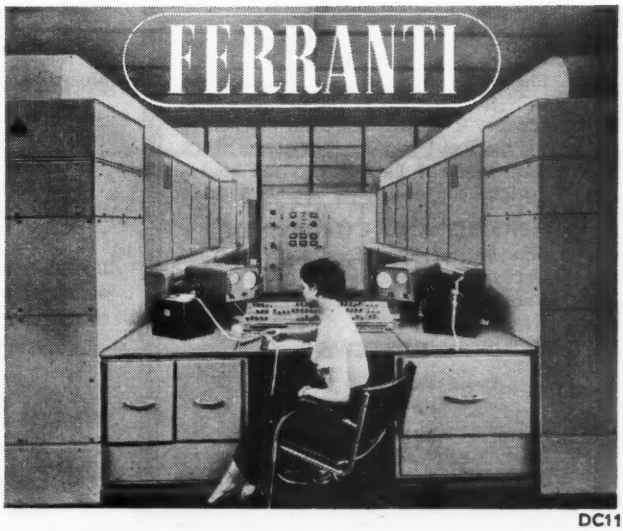
$$\frac{d}{ds}\left\{\left(1-\frac{x^2+y^2}{2}\right)\frac{dx}{ds}\right\}+x+\lambda\sqrt{x^2+y^2-\left(x\frac{dy}{ds}-y\frac{dx}{ds}\right)^2}\left\{y+\frac{dz}{ds}\left(x\frac{dy}{ds}-y\frac{dx}{ds}\right)\right\}=0$$

$$\frac{d}{ds}\left\{\left(1-\frac{x^2+y^2}{2}\right)\frac{dy}{ds}\right\}+y+\lambda\sqrt{x^2+y^2-\left(x\frac{dy}{ds}-y\frac{dx}{ds}\right)^2}\left\{-x+\frac{dz}{ds}\left(x\frac{dy}{ds}-y\frac{dx}{ds}\right)\right\}=0$$

$$\left(\frac{dx}{ds}\right)^2+\left(\frac{dy}{ds}\right)^2+\left(\frac{dz}{ds}\right)^2=1$$

300 operators using ordinary desk machines would have been needed to solve this problem in the time taken by the Electronic Digital Computer. Ferranti Computers are being applied to many problems in pure and applied science, mathematics, aircraft and general engineering design, petroleum products, commerce and statistics. Write for illustrated brochure.

Manufactured under licence from the National Research Development Corporation.



Ferranti Ltd · Moston · Manchester 10
London Office: Kern House, 36 Kingsway, W.C.2.

DC11

ROYAL TECHNICAL COLLEGE SALFORD

Principal:
P. F. R. VENABLES, Ph.D., B.Sc., F.R.I.C.

FULL-TIME AND PART-TIME DEGREE COURSES in Engineering, Chemistry, Physics, Mathematics, Biology.

FULL-TIME HIGHER DIPLOMA AND ASSOCIATESHIP COURSES in *Building, *Civil Engineering, *Structural Engineering, *Gas Engineering (Production and Distribution), Chemistry and Applied Chemistry, *Electrical Engineering, *Mechanical Engineering, *Textiles, *Chemical Engineering.

* With industrial or practical professional experience.

FULL-TIME COURSES in Art, Domestic Science, Intermediate Pharmacy, First Medical, *Chiropody, *Sanitary Inspection, *Bakery.

* With industrial or practical professional experience.

Prospectuses of the various courses may be had from the College on application.

R. RIBBLESDALE THORNTON,
Clerk to the Governors.

BABCOCK *films*

ON FREE LOAN to Engineering and Scientific Associations, Universities, Technical Colleges, Schools, etc.

Sound films. Available in both 16 mm. and 35 mm. sizes.

STEAM	(*Showing time, 40 mins.*)
PULVERISED FUEL	(*40 mins.*)
COMBUSTION AND THE CHAIN GRATE STOKER	(*25 mins.*)
FORGING	(*14 mins.*)
SEAMLESS TUBE MAKING	(*17 mins.*)
FOUNDRY PRACTICE	(*26 mins.*)
WELDING IN BOILER MANUFACTURE	(*18 mins.*)
CRAFTSMEN WELDERS	(*23 mins.*)

SYNOPSIS AND FILM BOOKING DETAILS *from*

BABCOCK & WILCOX LIMITED

Head Office:
BABCOCK HOUSE, FARRINGDON ST., LONDON, E.C.4

BJPS

The British Journal for the Philosophy of Science

CONTENTS FOR FEBRUARY 1955

ARTICLES

The Present Position in Probability Theory — HAROLD JEFFREYS
On the Notion of Invariance in Classical Mechanics — J. C. C. MCKINSEY and PATRICK SUPPES
Laboratory v. Field Research in Psychology and the Social Sciences — VIRGINIA BLACK
Utility Service in Field Physics and Mathematical Economics — ANDREW PICKLER

NOTES AND COMMENTS

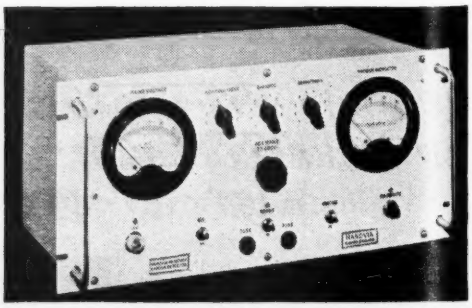
A New Interpretation of Gravitation — R. O. KAPP
Note on the Structural Philosophy of Organism — L. L. WHYTE

REVIEWS

Annual Subscription 30s post free
Single Copies 7s 6d (postage 3d)

NELSON

PARKSIDE WORKS EDINBURGH



MERCURY VAPOUR DETECTION *in industry*

The toxic nature of only 15 microgrammes of Hg Vapour in 1 cubic metre of air in a confined space can prove a real hazard to operatives. Traces of Hg Vapour can interfere with semi-conductor research work and certain chemical processes. In contrast sub-toxic traces of Hg Vapour can be introduced into pressure lines to locate minute leaks, using the Hg Vapour Detector.

HANOVIA

Specialists in ultra-violet ray equipment

HANOVIA · SLOUGH · BUCKS T60

THE BRITISH INTERPLANETARY SOCIETY

The B.I.S., with over 2,500 members, is now the largest organisation in the world devoted to astronautics. Its *Journal* publishes lectures presented to the Society, gives an extensive news coverage, and contains a complete classified and indexed abstracting service on rocketry and allied sciences.

Membership is open to all; Fellowship requires degrees or equivalent qualifications. Rates are as follows: Entrance Fee, 10/6; Fellowship, £2.12.6; Membership, £1.11.6 (£1.1.0 if under 21).

Details of the Society and its lecture programme may be obtained from the Secretary at:

12 Bessborough Gardens,
London, S.W.1
(Tel. TATe 9371)

READY SHORTLY

SELECTED METEOROLOGICAL PAPERS OF SIR WILLIAM NAPIER SHAW, F.R.S.

Selected and edited by R. G. K. LEMPFERT, M.A., and Miss E. E. AUSTIN, M.A.
11½ × 8¾ in. Line and two-colour charts.
256 pages. 50s. net.

JUST PUBLISHED

SURVEYING

Solutions to B.Sc. (Eng.) Examination Questions, London University (External) D.H.McPHERSON, B.Sc., M.I.C.E. and P. N. RAY, M.A. (Oxon.).
8¾ × 5⅝ in. 152 pages. 82 figs. 18s. net.

OTHER IMPORTANT VOLUMES

ELECTRO-MAGNETIC MACHINES

R. LANGLOIS-BERTHELOT, M.I.E.E., M.A.I.E.E. Translated and revised in collaboration with Lt.-Col. H. M. CLARKE, M.Sc., M.I.E.E.
8¾ × 5⅝ in. 544 pages. 309 figs. 65s. net.

DESIGN OF DIRECT CURRENT MACHINES L. GREENWOOD, M.I.E.E., M.I.Mech.E. "The book can be confidently recommended."—*The Times Review of Industry.*
8¾ × 5⅝ in. 222 pages. 25s. net.

MECHANICS OF MATERIALS

Professor E. P. POPOV, Ph.D.
8¾ × 5⅝ in. 441 pages. Fully illus. 70s. net.

MACDONALD & Co. (Publishers) Ltd.
16 MADDOX STREET, LONDON, W.1
'Phones: MAYfair 1064, 5841-2

Research . . .

Each of the many producing units of this organisation has its own research laboratories, but the specially equipped Research and Development Department now centralised in the new Swinden Laboratories at Rotherham has a wider and more fundamental function.

THE UNITED STEEL COMPANIES LTD

It covers the whole iron and steel making field, from the raw materials to the finished product and consequently necessitates close co-operation not only with other steel companies in Great Britain and abroad, but also with allied workers in numerous research associations and universities. A brochure describing the equipment and activities of the department is available on request.

THE UNITED STEEL COMPANIES LIMITED, 17, Westbourne Rd., SHEFFIELD 10

Spottiswoode, Ballantyne & Co. Ltd

GENERAL PRINTERS AND BOOKSELLERS

We specialise in the production of all kinds of first-class letterpress printing, including colour work. We have a modern plant, and an experienced staff is under expert supervision.

Head Office: 1 NEW STREET SQUARE, LONDON, E.C.4
Telephone: Central 5284. Telegraphic Address: "Spottiswoode, Phone, London"

PITMAN BOOKS

An Introduction to the Biology of Yeasts

By M. Ingram, M.A., Ph.D. This book describes what the yeasts are and what they do. It begins with an introductory chapter describing the general nature of yeasts, and then deals with the metabolic processes. A section is devoted to the process of growth and reproduction, and the book closes with an account of the behaviour of the yeast colony, and its place in nature. The nutritive properties of the yeasts are also covered. Illustrated.
25/- net.

Variational Principles in Dynamics and Quantum Theory

By W. Yourgau, Dr.Phil., and S. Mandelstam, B.Sc.(Eng.), B.Sc.(Rand). A work for post-graduate research students, physicists, mathematicians and philosophers of science which covers variational principles from their source to their development so as to derive the formulae of optics, dynamics and electro-dynamics. 25/- net.

Electric Traction

By A. T. Dover, M.I.E.E., A.M.Amer.I.E.E. An up-to-date Third Edition of this standard work for electrical engineers and advanced students. It follows the lines of the preceding editions in dealing with all the essential principles of the subject together with representative examples of railway and road vehicles and their equipment. Profusely illustrated. 60/- net.

Reinforced Concrete Arch Design

By G. P. Manning, M.Eng., M.Inst.C.E. A Second Edition of this practical textbook which provides structural engineers and advanced students with a theoretically sound and easily applied method to give the most economical shape and thickness of arch in any given case. Illustrated with diagrams and drawings, as well as a selection of photographic plates showing views of works both in progress and completed. 30/- net.

Inorganic Qualitative Analysis: Semi-Micro Methods

By H. Holness, M.Sc., F.R.I.C. An essentially practical book to be used "on the bench." The whole work has been thoroughly tested in practice and every experiment described has been tried out with classes of students. All students, up to and including those sitting for the B.Sc. general examination in chemistry for London University, will find this a most useful book. 12/6

Insects and Spiders

By C. P. Friedlander, B.Sc., A.R.C.S., F.R.E.S., and D. A. Priest, B.Sc., A.R.C.S., F.Z.S. A work of reference which classifies insects and spiders in a simple yet scientific manner. A book for the senior forms of schools for use in their standard field-work projects and also for first-year students taking a general biological degree course. 6/6

SIR ISAAC PITMAN & SONS LTD. *Parker St · Kingsway · London, W.C.2*

From the Government Bookshops

Islamic Law in Africa

J. N. D. ANDERSON

A survey of the application of Islamic law in the British Colonial Territories in Africa and the Colony and Protectorate of Aden.
50s. (by post 50s. 8d.)

The Petrology of Graham Land

Part I : The Basement Complex; Early Palaeozoic Plutonic and Vulcanic Rocks

R. J. ADIE, B.SC., PH.D.

The first of a series of five reports in which it is hoped to give a comprehensive account of all the accumulated field observations of the Falkland Islands Dependencies Survey in Graham Land since 1946.
Illustrated. **8s. 6d.** (by post 8s. 10d.)

The Dielectric Properties of Wood

R. F. S. HEARMON, F.INST.P.
J. N. BURCHAM, B.SC.

Measurements of permittivity and loss tangent on twelve species of wood at various moisture contents and frequency ranges are summarised and discussed.
(*Forest Products Research Special Report No. 8.*)
1s. 6d. (by post 1s. 7½d.)

Colonial Research, 1953-54

A compendium of research work undertaken by eleven organisations throughout the Colonial Empire. (Cmd. 9303.)
7s. 6d. (by post 7s. 10d.)

HER MAJESTY'S STATIONERY OFFICE

York House, Kingsway, London W.C.2; 423 Oxford Street, London W.1 (Post Orders: P.O. Box 569, London S.E.1); 13A Castle Street, Edinburgh 2; 39 King Street, Manchester 2; 2 Edmund Street, Birmingham 3; 109 St. Mary Street, Cardiff; Tower Lane, Bristol 1; 80 Chichester Street, Belfast; *or through any bookseller*

THE PHYSICAL SOCIETY'S
39th EXHIBITION
of
SCIENTIFIC INSTRUMENTS
AND APPARATUS
will be held at the
ROYAL HORTICULTURAL
SOCIETY'S NEW HALL
Greycoat and Elverton Streets,
Westminster, S.W.1
From 25th to 28th April, 1955

The Handbook, which will be published in connection with the exhibition, is not only a catalogue, but is a most valuable reference book of new developments in British scientific instruments and apparatus.

During the Exhibition discourses on scientific subjects of general interest will be given.

The Annual Craftsmanship and Draughtsmanship Competition takes place early in the year, and the winning entries will be exhibited.

1, Lowther Gardens,
Prince Consort Road, London, S.W.7

BOOKS
ON
NATURAL HISTORY
AND
BIOLOGY

New, Second-hand, Old and Rare

CATALOGUES ON REQUEST

WHELDON & WESLEY,
LTD.
83/84 BERWICK STREET
LONDON, W.1. Phone: GER 6459

THE ADVANCED ATLAS
OF
MODERN GEOGRAPHY
By JOHN BARTHOLOMEW, M.C., F.R.G.S.
NEW SERIES. THIRD EDITION

An essential atlas for any person who takes an intelligent interest in world affairs today. The coast and river outlines in blue makes for clarity and ease in reading. It has been completely revised to show the most recent world changes, and is unsurpassed for quality and detail of information.

Size : 14½" × 10". Bound in red buckram

PRICE : 30/-

A DETAILED CATALOGUE SENT FREE ON REQUEST

MEIKLEJOHN & SON LTD.
15 BEDFORD ST., LONDON, W.C.2

VARIAC INFINITELY VARIABLE
AUTO-TRANSFORMERS

The original and still by far the best and most reliable manual control of a.c. voltage. Compared with the losses of resistive controls the "VARIAC" usually saves its cost within about one year. Available in various sizes from 170 VA to 25 kVA, they are very reasonable in price. Two-gang and 3-gang assemblies (for 3-phase work) are also always available promptly.

We shall be pleased to send you our 32-page Technical Manual, free and post free. Request "V-549 (3rd Edition)."

AUTOMATIC VOLTAGE STABILISERS

We can offer a complete range of automatic voltage stabilisers from 200 VA to about 25 kVA, single phase. Three-phase stabilisers are also available promptly. These instruments are frequency-insensitive, and the output is entirely free from harmonics. Our 20-page Catalogue V-549-S will gladly be sent free and post free on application.

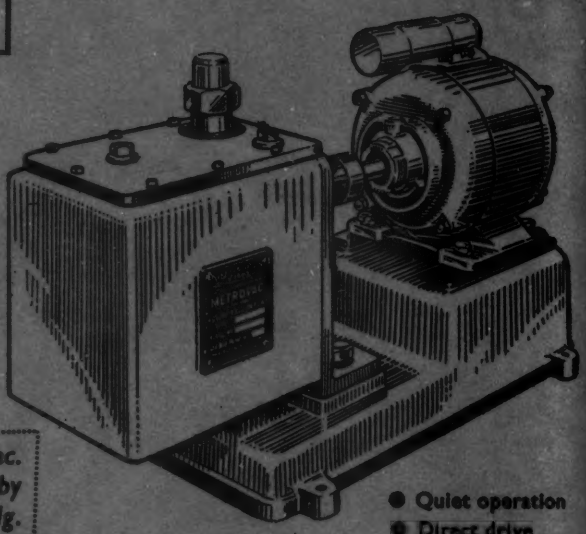
Head Office & Works:
76 Oldhall Street, Liverpool 3, Lancs.
Southern Factory:
Valley Works, Ware Road, Hoddesdon, Herts.
(A.10 main London/Cambridge Road, at junction of A.602)

Quiet Efficiency

DR1 METROVAC 2-STAGE ROTARY VACUUM PUMP

An oil-immersed vane-type pump having a direct drive with integral gearing. There is very little vibration or noise when the pump is running—an important consideration in many laboratories.

Displacement . . . 1.0 litre per sec.
Ultimate pressure as measured by McLeod gauge . . . 0.0005 m.m. Hg.
Normal speed of pump rotor 370 r.p.m.



- Quiet operation
- Direct drive
- Please write for leaflet 435/18-1

METROPOLITAN-VICKERS

Member of the A.E.I. group of Companies

N/P401

RAILWAY MOTIVE POWER

HARRY WEBSTER, B.Sc., M.I.Loco.E.

A full account of the various methods of train driving from earliest times to the present day, including steam, electricity, diesel and jet turbine. With a foreword by Lt.-Col. HAROLD RUDGARD, O.B.E., formerly Chief Officer, Motive Power, British Railways. 30/-

GENERAL PRINCIPLES OF GEOLOGY

J. F. KIRKALDY, D.Sc., F.G.S.

A new text-book for University students by the Head of the Geology Department of Queen Mary College, London. Modern theory is adequately covered but practical and economic applications of geology from water-supply to road-making are by no means overlooked.

"An invaluable asset to the school reference library."—*Teachers' World.* 25/-

The above books are fully illustrated.

Full Catalogue available on request

HUTCHINSON'S

SCIENTIFIC AND TECHNICAL PUBLICATIONS

11, Stratford Place, London, W.1.

Printed in Great Britain by Spottiswoode, Ballantyne & Co. Ltd., London and Colchester